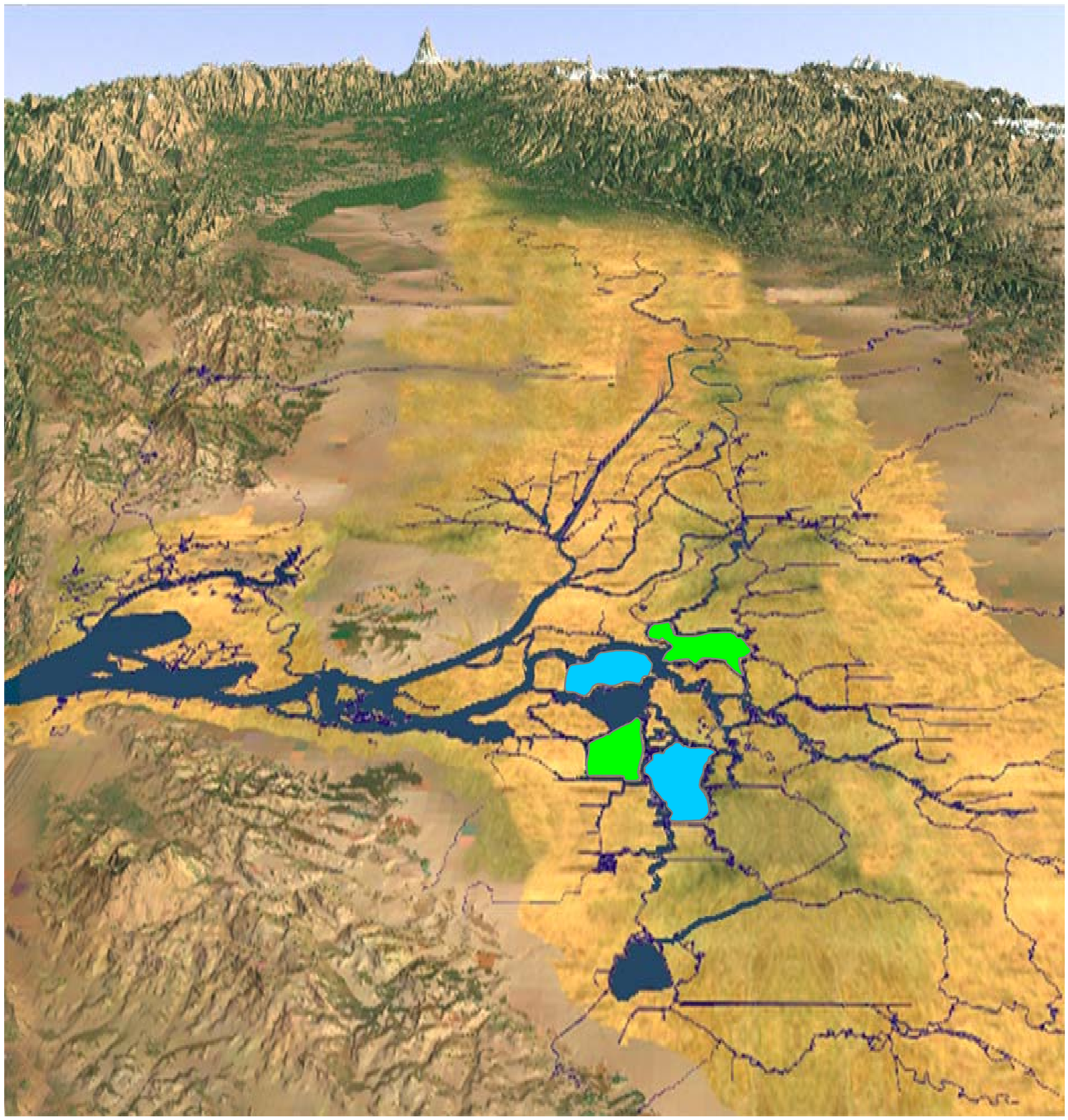
INTEGRATED STORAGE INVESTIGATIONS

IN-DELTA STORAGE PROGRAM
DRAFT REPORT ON OPERATION STUDIES



CALFED BAY-DELTA PROGRAM

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Chapter 1
INTRODUCTION

1.1 General

In-Delta storage will help meet CALFED's goals of increased environmental flows, improved water quality, water supply and facilitating water transfer and conjunctive use programs. Operation studies of in-Delta storage were conducted to determine potential capability of project to supply water for environmental enhancement and urban and agricultural uses and also increase operational flexibility of the Central Valley Project (CVP) and the State Water Project (SWP). Any water diverted to in-Delta storage is within the inflow/outflow export ratio and is already covered by the existing CVP/SWP water rights. A comparison of CALSIM-II Model results between the base and with project was used to assess the effect of in-Delta storage on water supplies, hydrodynamics of the Delta channels, Delta water quality and the operation of reservoirs north and south of the Delta. The CALSIM-II Model was used to conduct operation studies to assess the operational flexibility and water supply benefits of the project. The hydrodynamics and water quality impacts of in-Delta storage were assessed later by using the results of these operation studies as input to the DWR Delta Simulation Model (DWR DSM2). In CALSIM-II modeling studies, the modeled conditions in a particular year will not conform to the historic observed conditions for the same year. The purpose of the model is not to recreate historic conditions but to predict potential conditions under various system, regulatory and water demand scenarios

This report presents information on operations modeling studies conducted with the joint Reclamation/DWR recently developed new CALSIM Model. A brief description of the CALSIM-II Model is given. Results of the in-Delta storage operations are compared with the Base case study representing conditions without project.

1.2 In-Delta Storage Operation Criteria

The Delta Wetlands (DW) Project was first proposed in 1987. The original plan was to convert the four islands (Webb Tract, Bacon Island, Holland Tract and Bouldin Island) from agricultural use to seasonal reservoirs. In 1995, the Project was redesigned to convert two islands – Webb Tract and Bacon Island- to year-round reservoirs and to convert the other two islands – Bouldin Island and most of Holland Tract – to year-round waterfowl and wildlife habitat. DW Properties applied to the California State Water Resources Control Board (SWRCB), Division of Water Rights, for the necessary permits to divert water and store it on Project Islands. DW also applied to the U.S. Army Corps of Engineers (USACE) for a permit under Section 404 of the Clean Water Act. SWRCB was the Project's lead agency under the California Environmental Quality Act (CEQA), and USACE was the Project's lead agency under NEPA. These lead agencies prepared the draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) in 1995 to comply with the regulatory requirements of both CEQA and NEPA. This draft analyzed the environmental effects, and identified and assessed alternatives to the proposed action.

Three Biological opinions have been prepared since the 1995 DW EIR/EIS. On May 6, 1997, the U. S. Fish and Wildlife Service issued its final biological opinion and conference opinion concerning the effects of the Project on delta smelt and Sacramento spittail. On May 7, 1997, the National Marine Fisheries Service issued it's final biological opinion concerning the effects of the Project on the winter-run chinook salmon and steelhead. On August 6, 1998, the California Department of Fish and Game issued its revised biological opinion concerning the effects of the Project on winter-run chinook salmon and delta smelt. All three biological opinions were incorporated in the Operations Criteria (OC) set forth in Decision 1643 adopted by the State Water Resources Control Board (SWRCB). This decision conditionally approves the water right applications and petitions needed to appropriate water by direct diversion and storage to reservoirs on Webb Tract and on Bacon Island. The project operated according to the OC rules will not jeopardize any listed species under the Federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

A water rights permit was issued to DW Properties with conditions as per SWRCB's Decision 1643. Also, project is required to meet additional conditions under the CUWA Agreement Water Quality Management Plan (WQMP). Operations criteria based on SWRCB Decision 1643, WQMP and biological opinions are given in Table No. 1.

Table 1 – Operation Criteria for In-Delta Storage

CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FLOW STANDARDS												
*** DIVERSION TO STORAGE** [1]												
D1643 Diversion Criteria												
No Diversion to Storage												
Initial Delay Period-X2 days past Chipps (75km)		10 days								10 days		
Initial Ramping Period -5,500 cfs max		5 days								5 days		
Min 14-day running avg of X2 requirement				X2 < 75 km								
Min 14-day running avg of X2 requirement	X2 < 81 km						X2 < 81 km					
Min 14-day running avg of X2 requirement when delta smelt are present at CCWD intake.												X2 < 81 km
Proj. Div is 500 cfs if 14-day running avg of X2		81 <X2 >80 km							81 <X2 >80 km			
Project Div is 1,000 cfs if 14-day running avg of X2		X2 >81 km							X2 >81 km			
Maximum allowable X2 shift (location)		2.5 km								2.5 km		
Limit on % of Net Delta Outflow	15 %	15 %	15 %	0 %	0 %	25 %	25 %	25 %	25 %	25 %	25 %	25 %
Max. Annual Diversion to Storage					Webb Tract -262 taf/year, Bacon Island - 258 taf/year							
Biological Opinion Diversion Criteria												
Initial Diversion for Water Year		X2 < 74 km								X2 < 74 km		
Minimum X2 requirement (location)		X2 < 81 km								X2 < 81 km		
Limit on % of surplus water	90 %	75 %	50 %	0 %	0 %	50 %	75 %	90 %	90 %	90 %	90 %	90 %
Limit on % of SJR - 15 days per month	125 %	125 %	50 %									125 %
Limit Diversions during DXC Closure												
Limit Div to 550 cfs unless QWEST remains +ve												
Maximum Top-Off Diversion Rate [2]						215 cfs	270 cfs	200 cfs	100 cfs	33 cfs		
Reduce Diversion to 50% of previous days diversion rate if Delta Smelt are present												
*** DISCHARGE FOR EXPORT** [3]												
D1643 Discharge Criteria												
Webb Tract (max 2,000 cfs)												
Fixed prohibitions				No discharges for export								
Limit on % of available export capacity							75 %					
Bacon Island (max 4,000 cfs)												
Limit on % of SJR inflow				50 %	50 %	50 %						
Limit on % of available export capacity		75 %	50 %	50 %	50 %	50 %	75 %					
Max. Chloride conc. Increase at CCWD intake						10 mg/l 14-day running average						
Zero salinity increase if it is already exceeding 90% of standard.												
Max. Annual Release of Stored Water							822 taf / year					
Max. Annual Export of Stored Water							250 taf / year					
Biological Opinion Discharge Criteria												
Reserved Environmental Water [4]	10 %	10 %	10 %	10 %	10 %	10 %						10 %
Limit Discharge for export to 50% of previous days diversion if Delta Smelt are present												

Footnotes

[1] Maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cfs. The combined maximum daily average rate of diversion for all islands (including 200 cfs diversions to each of the habitat islands) will not exceed 9,000 cfs.

[2] Water will be diverted onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, referred to as topping-off reservoirs. The maximum topping-off diversion rates shall be reduced by an amount equal to the habitat island diversions during the same period.

[3] Discharges will be pumped at a combined maximum daily average rate of 6,000 cfs. Discharge is subjected to export limits, treated as an export in the monthly E/I ratio computation except when water is discharged for environmental water account.

[4] A quantity of "environmental water" will be provided for release as additional Delta outflow equal to 10% of all discharges for export that occur in the period of December thru June.

1.3 Operation Study Procedures

Procedure used to determine benefits of the In-Delta storage project included simulation of the base case conditions without project. A monthly CALSIM-II Model was modified to a daily time step model for the Delta configuration. North of Delta and South of Delta evaluations were done with the monthly model. The daily model for the Delta was further modified to include the DW Project's four islands: Webb Tract, Bacon Island, Bouldin Island and Holland Tract. For evaluation of other alternatives, model capability was increased to include Victoria Island and connection to Clifton Court Forebay. To evaluate the impact of water quality constraints on the project yield, CALSIM-II Model studies were conducted with and without water quality constraints.

The results of the following studies are presented in Chapter 4 of this report.

- Base case operations
- In-Delta storage study with Webb Tract and Bacon Island as storage reservoirs with 6000 cfs maximum daily diversion to storage. This study did not have any delta smelt and DOC constraints.
- In-Delta storage study with Webb Tract and Victoria Island as storage reservoirs with 6000 cfs maximum daily diversion to storage. A 2000 cfs siphon connects Victoria Island to Clifton Court Forebay. This study did not have any delta smelt and DOC constraints.
- Delta Wetlands study with delta smelt, 1997 U.S. Fish and Wildlife Service (USFWS) Fall Mid-Water Trawl (FMWT) Index constraints
- Delta Wetlands study with DOC constraints
- Impact of climate change

1.4 Findings, Conclusions and Recommendations

1.4 1 Key Findings and Conclusions

Operational modeling studies conducted using the SWRCB, WQMP, and DFG and USFWS criteria indicate:

- Based on the 73-year historical period daily modeling with a 2020 level of development and hydrology, DW Project provides an average annual increment in south of Delta SWP and CVP water supplies of 126 taf/year. This estimate is primarily for comparison purposes only. The DW Project can also be operated for priorities other than augmenting south of Delta SWP and CVP water supplies.
- Preliminary results of the In-Delta storage study with Webb Tract and Victoria Island with direct connection to Clifton Court Forebay show an average annual yield of 123 taf.
- Based on the preliminary modeling for the 1975 to 1991 period, U.S. Fish and Wildlife 1997 Operations Criteria for decline in delta smelt abundance is expected to reduce the yield of the DW Project by 20 taf.
- Based on preliminary modeling, for DOC, a yield reduction of 16taf occurs for the high bookend DOC value. Average annual delivery is not impacted for the low bookend DOC value.
- Preliminary climate change assessment shows In-Delta storage will be effective in capturing early winter flows resulting from change in flow patterns due to potential climate change.

1.4.2 Recommendations

- Further evaluations are needed to allocate water supply benefits between south of Delta exports, EWA CVPIA, water banking and transfers. Daily CALSIM-II Modeling should continue for quantitative determination of project water use for environmental, CVPIA and other purposes in addition to South of Delta exports.
- There is a need to hold further discussions on the fisheries criteria application in light of DW Project being included as a CALFED project.

Chapter 2
STUDY ASSUMPTIONS

2.1 Assumed Level of Development

2020 level of development was assumed for operation studies to determine the new or additional yield that a proposed alternative would generate above the base conditions. The studies use a historical 73-year hydrologic sequence of flows from water years 1922 through 1994 as input. The hydrologic sequence is adjusted to reflect the effect of estimated 2020 level and use patterns. This adjustment is developed using two other models: the Consumptive Use model and the Depletion Analysis model. The hydrology is also modified to account for current operations of local upstream reservoirs. Delta is a vital link for the state's water supply. Forty-two percent of the state's annual runoff flows through this maze of islands, marshes and sloughs. State and federal water facilities located in the south Delta pump water to supply farms and cities in central and southern California, providing water to about two-thirds of the state's population and provide minimum required delta outflow. These minimum requirements are assumed to meet 1995 SWRCB's Water Quality Control Plan objectives, and allow Delta exports within the export/inflow ratio and the permitted pumping capacity. The recent SWRCB decision 1641 allowed south of Delta use of Tracy and Banks Pumping Plants for joint point diversion to the Central Valley and the State Water Projects.

2.2 Potential Uses

New surface storage is essential to meet CALFED's goals of increased environmental flows, improved water quality, water supply and facilitating water transfer and conjunctive use programs. In-Delta storage will increase water supplies, particularly in summer and dry periods, to meet existing shortages and accomplish these goals. It will also increase flood control protection, provide groundwater recharge and recreational benefits not afforded by classic demand management recommendations. Various uses of the new storage are as follows.

2.2.1 Improvement in System Operational Flexibility

In-Delta storage will provide CVP/SWP operational flexibility by providing water storage space in the Delta for environmental flow capture, wet and operational spills, delta outflow, water transfers, conjunctive use, CVPIA (b)(2) and Environmental Water Account (EWA).

2.2.1.1 Environmental Flow Capture

Environmental flow releases from upstream reservoirs to maintain water quality objectives or provide environmental water to support both resident and anadromous fisheries can be captured by in-Delta storage. Many of these releases are for meeting upstream flow standards and may not have a corresponding requirement in the Delta. Therefore, these releases may be surplus to Delta needs. During given times of the year, in the various reaches of the Sacramento river, operators my release cold water to meet temperature criteria rather than required minimum flows. This project can recapture these flows particularly in the years when upstream reservoir releases are greater than desired for water supply alone. So, the environmental releases could be captured and stored until sufficient demand calls for the export of the water, or until such time as the conveyance capacity is available to export the water south of the Delta.

2.2.1.2 Facility Reoperation

This project would provide downstream storage for operational and wet weather spills from upstream reservoirs. This project would add flexibility to the operation of upstream reservoirs because the fear of "losing the water" to the ocean would be reduced. The ability to delay the release of water from upstream facilities, because of a water source available in the Delta to meet in-Delta or Delta export needs, could be significant in terms of operation flexibility later in the water year.

2.2.1.3 Delta Outflow and Water Quality Requirements

In-Delta storage water could be used to meet export and Delta water quality objectives more quickly than upstream reservoirs, providing greater operational flexibility. This water would be used to meet outflow needs on an emergency basis or to "fine-tune" the releases for outflow to avoid over or under releasing water.

2.2.1.4 CVP/SWP Operations

In-Delta storage would allow fine-tuning of CVP/SWP operations. Water stored in the project could be used just like other sources of stored water to meet export demands or Delta outflow requirements. Delta outflow standards could be met from the Project in lieu of upstream reservoir releases. Because this source of water is close to its eventual use, the efficiency of meeting these demands should improve. This is because less water is needed to meet outflow when the demands are met from the Delta compared with a release from reservoirs, which would also have carriage water requirements to convey the water from upstream. Any reduction in releases would increase the cold water available in those releases for in-stream fishery flows.

2.2.1.5 Interior Delta Water Quality

It would be quicker to respond to the water quality conditions in the Delta than with the upstream reservoirs. The immediate response could help offset water quality problems created from a toxic spill, levee break, or localized conditions.

2.2.1.6 Water Transfers

In-Delta storage project could provide available storage capacity to buyers and sellers for water transfers from north of Delta users to south. This project could assist in scheduling transfers. Water Stored in in-Delta Storage could be used in lieu of the upstream reservoir releases for export or be available for later use by retaining a larger cold water pool in these reservoirs.

2.2.1.7 Joint Point of Diversion

A joint CVP/SWP facility would significantly increase the use of this stored water. Banks Pumping Plant wheels water for the CVP and EWA when there is excess capacity at Banks Pumping Plant. In-Delta storage project will assist in storing storage withdrawals of CVP water for wheeling By Banks Pumping Plant into CVP San Luis Reservoir. EWA water temporarily stored in in-Delta storage project will be transferred by Banks Pumping Plant to the EWA storage account in San Luis Reservoir.

2.2.1.8 Environmental Water Account (EWA)

The EWA largely relies on water transfers from Northern California to fund the account during the initial years. Due to limited upstream opportunities in the Sacramento Valley for CALFED Agencies to purchase or otherwise develop water assets, in-Delta storage can provide space for EWA water. EWA will help add flexibility to the water system to ensure that fish are protected from water project operations while allowing for greater water supply reliability for agricultural and urban users.

2.2.1.9 Conjunctive Use Program

Flows captured in the in-Delta storage could benefit the conjunctive use program. Conjunctive use is a set of water management techniques that store surface water underground in times of abundant supply for use in dry years when shortages are being experienced. In-Delta storage could be a key element in conjunctive use program, either by providing surface water to a groundwater extractor, thereby facilitating in lieu recharge, or by providing surface water to recharge facilities for artificial recharge of a groundwater basin.

2.2.2 Water Supply Benefits

2.2.2.1 CVPIA (b)(2)

The CVP dedicates 800 taf per year from project yield to fish and wildlife restoration under CVPIA Section 3406 (b)(2). The water allocated to (b)(2) is equivalent to a new water demand on the CVP system. In dry years, water would be released from project facilities or pumping curtailed to meet this water demand. In wet years, when ample water is flowing through the Delta, similar actions would be required to meet the demand. In-Delta storage Project could help meet this new demand. During wet years, water could be stored on Project islands during high flows and released during the drier summer months to meet the (b)(2) demand. This could take place in lieu of pumping curtailments. Because this demand is present in all year types and is not reduced by hydrologic factors that may reduce agricultural demands, the net effect of this demand would be to increase the in-Delta storage project's yield.

2.2.2.2 Refuge Water Supply

CVPIA requires firm Level 2 water supplies to national wildlife refuges to equal annual historical water deliveries (Level 2). Additional water is to be provided for optimal wildlife management (Level 4) within 10 years of enhancement. In-Delta storage project could help meet Level 2 and Level 4 refuge demands that would otherwise be met through existing storage. Refuges generally require water year-round. Peak requirements occur in the fall, with flooding of seasonal marshes. The south-of-Delta refuge and wildlife areas could be served by specific releases from the Project in the fall when typical supplies are not available. In addition, refuges north and south of the Delta could indirectly benefit from the Project because the overall yield of the CVP would be increased, increasing the system's flexibility, reliability, and delivery capability.

2.2.2.3 Municipal and Industrial (M&I) and Agricultural Demand

In-Delta storage will meet the M&I and agricultural demand when pumping capacity exists at the Tracy and Banks Pumping Plants. This water could be used directly to meet demands or could be temporarily stored in San Luis Reservoir.

2.2.3 Water Supply Reliability

Water supply reliability is improving the predictability and availability of economic benefits derived from water while restoring ecosystem health in the Bay-Delta estuary and watershed. Many urban water managers worry about California's water supply reliability during an extended drought. Keeping water in the state's elaborate network of canals, reservoirs and aquifers is of the highest importance for a state so dependent on water for its economic stability. In-Delta storage project would help improve water supply reliability for urban and agricultural water users and the environment. It will increase the predictability of water availability during dry years.

2.2.4 Short term storage for Water Marketing

Water marketing – the sale, exchange, or lease of water from one user to another – has the potential for becoming a key tool for meeting rising water demand. It allows water agencies to purchase additional water supply reliability during both average and drought years. In-Delta storage can help augment the statewide water supply by providing surface storage for exchange, sale or lease among users.

2.3 Assumptions for Operation Studies

2.3.1 Base Case Water Supply

For computing project yield, the base case above which the new project would supply additional water is important. Two main considerations for selection of this base case were hydrology and water demands. It was assumed that the system would be operated according to State Water Resources Control Board's (SWRCB's) Water Rights Decision 1641, and 2020 Level of Hydrology and Demands. A 2020 level no action condition was defined to represent a reasonable range of uncertainty in the pre-implementation condition. Although a land use change is expected from the present to the 2020 level planning horizon, hydrological studies indicate that future 2020 level hydrology based water supply may not show appreciable change. With the increase in population, water demands are expected to change. These demands include a total annual State Water Project demand that varies between 3.6 MAF and 4.2 MAF. The maximum interruptible demand is 134 taf per month. The total annual Central Valley Project demand is 3.5 maf. This includes the annual Level II Refuge demand of 288 taf. Cross Valley Canal demand is 128 taf/year. Banks Pumping Plant export capacity of 10,300 cfs was used. Trinity River Minimum Fish flows below Lewiston Dam are maintained at 340 taf/year.

2.3.2 In-Delta Storage Operation Assumptions

The modeling assumptions for the In-Delta storage project Study include the terms set by the SWRCB and the assumptions of the Base Study. A conditional Biological Opinion was issued by U.S. Fish & Wildlife Service in 1998 and the operating criteria stated in the Biological Opinion were applied to all in-Delta studies. In-Delta storage studies were performed by incorporating all the criteria stated in the SWRCB Decision 1643, WQMP and three fisheries Biological Opinions. All common assumptions applied to the Base Case were also applied to the in-Delta studies.

As in the Base Case, 2020 Level of Hydrology and Demands were used in in-Delta storage operations. The daily CALSIM-II Model configuration included DW Projects Webb Tract and Bacon Island reservoirs. The permitted diversions to Holland and Bouldin habitat islands were included in the modeling. Based on conditions included in the SWRCB water rights permit, the following assumptions have been developed for in-Delta storage studies.

2.3.2.1 Diversion Criteria

- DW Projects diversion to storage could only occur when the volume of allowable water for export (i.e., the lesser of the amount specified by the export limits and the amount of available water) is greater than the actual pumping at Banks and Tracy Pumping Plants. This would occur under the following conditions:

    - All Delta outflow requirements are met.

    - Export limit is greater than the actual pumping at Banks and Tracy P.P. when they are pumping at or below the physical pumping capacities as allowed by the Corps Permit such that water that is allowable for export is not being exported by Banks and Tracy P.P.

- Initial diversions to DW Project shall not be made for the current water year (commencing October 1) until X2 has been west of Chipps Island (75 km upstream of the Golden Gate Bridge) for a period of ten (10) consecutive days. After initial X2 condition is met, diversions shall be limited to a combined maximum rate of 5,500 cfs for five (5) consecutive days.

- Maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cfs (9 taf/day). The combined maximum daily average rate of diversion for all islands (including diversions to habitat islands) will not exceed 9,000 cfs.

- The maximum annual amount diverted to Webb Tract storage shall not exceed 155 taf per year from January 1 to March 31 and June 1 to December 31 and shall not exceed 106,900 af per year from December 15 to March 31. The total amount of water taken from all sources shall not exceed 417 taf per water year of October 1 to September 30.

- The maximum annual amount diverted to Bacon Island storage shall not exceed 147 taf per year from January 1 to March 31 and June 1 to December 31 and shall not exceed 110,570 AF from December 15 to March 31. The total amount of water taken from all sources shall not exceed 405 taf per water year of October 1 to September 30.

- Diversions shall not exceed 1000 cfs when the 14-day running average of X2 is farther than 80 km upstream of the Golden Gate Bridge, nor exceed 500 cfs if the 14-day running average of X2 is farther than 81 km upstream of the Golden Gate Bridge.

- No Diversions to storage will be made if the Delta is in excess conditions and such diversions cause the location of the 14-day running average of X2 to shift upstream (east) such that X2 is:

- East of Chipps Island (75 river kilometers upstream of the Golden Gate Bridge) during the months of February through May, or

- East of Collinsville (81 kilometers upstream of the Golden Gate Bridge) during the months of January, June, July, and August, or

- During December, east of Collinsville and delta smelt are present at Contra Costa Water District's point of diversion under Water Right Permits 20749 and 20750.

- In the period from September through March DW shall not divert water to storage when X2 is located upstream of Collinsville salinity gauge.

- In the period from October through March, DW Project shall not divert water to storage if the effect of DW Project diversions would cause an upstream shift in the X2 position in excess of 2.5 km (i.e., increase the X2 by 2.5 km).

- In the period from April through May, DW Project shall not divert water to storage .

- If the delta smelt FMWT index is less than 239 (FMWT<239), DW shall not divert water for storage from February 15 through June 30.

- DW Project diversions to storage shall not exceed the following percentage of the available surplus water if FMWT Index > 239:

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Percent	90%	90%	90%	90%	75%	50%	0%	0%	50%	75%	90%	90%

If FMWT < 239, DW Project diversions to storage shall not exceed the following percentage of the available surplus water:

Month	OCT	NOV	DEC	JAN	FEB(1-14)	FEB(15-28) TO JUNE	JUL	AUG	SEP
Percent	90%	90%	90%	90%	75%	NA	75%	90%	90%

- DW Project diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate (assume FMWT Index > 239 scenario):

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Percent	25%	25%	25%	15%	15%	15%	0%	0%	25%	25%	25%	25%

If FMWT<239, DW Project diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate:

Month	OCT	NOV	DEC	JAN	FEB(1-14)	FEB(15-28) to JUN	JUL	AUG	SEP
Percent	25%	25%	25%	15%	15%	NA	25%	25%	25%

- In the period from December through March, DW Project Diversions to storage shall not exceed the percentage of the previous days San Joaquin River inflow rate:

  If FMWT Index > 239, this limit applies for 15 days during the December through March period whenever DW Project diverts water to storage.

Month	DEC	JAN	FEB	MAR
Percent	125%	125%	125%	50%

  If FMWT Index < 239, this limit applies for 30 days during the December through March period whenever DW Project diverts water to storage.

Month	DEC	JAN	FEB(1-14)	FEB(15-28)	MAR
Percent	125%	100%	50%	NA	NA

- For the month of March diversion to DW Project shall be reduced to 550 cfs in unless QWEST remains positive.

- Reduce diversion rate to 50% of the previous day's diversion rate during the presence of delta smelt.

- In the period from November through January, when the Delta Cross Channel gates are closed, DW Project shall limit diversions to storage as follows:

Delta Inflow	Max. combined Diversion Rate
<=30,000 cfs	3,000 cfs
<=50,000 cfs & >30,000 cfs	4,000 cfs

- Water will be diverted onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, referred to as "topping-off" reservoirs. Topping-off diversions shall not exceed the following maximum diversion rate (cfs) and maximum monthly quantity (taf) listed below:

Month	JUN	JUL	AUG	SEP	OCT
Maximum diversion rate (cfs)	215	270	200	100	33
Maximum monthly quantity (taf)	13	16	12	6	2

  The maximum topping-off diversion rates shown above shall be further limited by diversions onto the habitat islands. The maximum topping-off diversion rate and quantity shall be reduced by an amount equal to the habitat island diversions during the same period.

- From September through May, the reservoir islands may be flooded to shallow depths (1ft) to create 200 acres of shallow water rearing and spawning habitat, typically 60 days after reservoir drawdown. After shallow water flooding, water will be circulated till deep water flooding occurs in April or May.

- The maximum rate of proposed diversion onto Holland Tract and Bouldin Island will be 200 cfs per island. Diversions onto the habitat islands will not cause the combined daily average maximum diversion rate of 9,000 cfs for all four project islands to be exceeded. Water will be applied in each month of the year

2.3.2.2 Discharge Criteria

- Discharges will be pumped at a combined maximum daily average of 6,000 cfs. Combined monthly average reservoir island discharge will be up to 4,000 cfs. Maximum annual release of stored water would be 822 taf.
- Maximum Annual export of stored water would be 250 taf.
- No discharges shall be made for export from Webb Tract from January through June.
- In the period from April through June, DW shall limit discharges for export from Bacon Island to one-half (50%) of the San Joaquin inflow measured at Vernalis.
- DW shall not discharge for export any water from the habitat islands.
- Reduce the discharge for export rate to 50% of previous day's diversion rate during the presence of delta smelt.
- DW Project discharge is subject to export limits, treated as an export in the monthly E/I ratio computation except when water is discharged for environmental water account.
- In the period from February through July, DW discharges for export shall be limited to the following percentage of the available unused export capacity at the CVP and SWP facilities:

Month	FEB	MAR	APR	MAY	JUN	JUL
Percent (Bacon Island)	75%	50%	50%	50%	50%	75%
Percent (Webb Tract)	NA	NA	NA	NA	NA	75%

- DW shall reduce the discharge for export rate to 50% of the previous day's diversion rate during the presence of delta smelt.

2.3.2.3 Storage

Storage capacity of reservoir Islands is:

Webb Tract	100,664 acre-feet
Bacon Island	114,965 acre-feet
Victoria Island	107,978 acre-feet

2.3.2.4 Salinity Impacts

- Project Operations should not cause an increase in salinity or more than 10 mg/L chloride at one or more of the urban intakes: or
- Project Operations should not cause any salinity increase at the urban intakes in the Delta exceeding 90% of an adopted salinity standard (e.g., Rock Slough chloride standard defined in SWRCB Decision 1641Total Trihalomethanes (“TTHM”) concentrations in excess of 64 ug/L at urban intakes in the delta.

2.3.2.5 Water Quality Management Plan

The following Diversion and Release Criteria for in-Delta storage based on the Water Quality Management Plan (WQMP). In an effort to address California Urban Water Agencies, CUWA's water quality concerns, DW Properties proposed to implement a WQMP. The WQMP includes drinking water quality protection principles, an annual operating plan, general operating principles, a comprehensive monitoring program, screening procedures and operational constraints, and mitigation of water quality impacts. Some of the diversion and release rules to be provided by DSM2.

- Diversion/Release Criteria:
  - TOC Loading:
    - Project operations should not cause an increase in TOC of more than 1.0 mg/L at the urban intakes.
    - Project operations should not cause TOC concentrations at the urban intakes to exceed 4.0 mg/L.
    - Project operations should not cause TOC concentrations at a water treatment plant to exceed 4.0 mg/L.
  - DBP Formation:
    - Project operations should not cause Total Trihalomethanes ("TTHM") concentrations in excess of 64 ug/L at urban intakes in the delta.
  - Temperature and D.O. Requirements to be checked.

2.3.2.6 South Delta Barrier Operation

South Delta Barrier Biological Opinion Operation will be evaluated in DSM2.

Chapter 3
OPERATIONS MODELING

3.1 CALSIM-II Planning Model Description

CALSIM-II monthly model and CALSIM-II daily model were used as a comparative tool to compare in-Delta storage to a baseline simulation. A new Daily Delta CALSIM-II Model was developed for the estuary and the CVP/SWP export and conveyance facilities south of the Delta. Figure 1 shows the CALSIM-II Daily Delta Model Schematic. A brief description of these models is given in the following sections.

3.1.1 Monthly CALSIM-II Model

CALSIM-II is a general-purpose Water Resource Systems Model, developed jointly by US Bureau of Reclamation (Reclamation) and DWR to simulate operation of the Federal Central Valley Project (CVP) and the California's State Water Project (SWP) System of reservoirs and conveyance facilities. CALSIM-II uses optimization techniques to efficiently allocate water through a network of nodes and arcs, given user-defined priority weights. A mixed integer/linear programming (MILP) solver determines an optimal set of decisions for each time period given a set of weights and system constraints.

CALSIM-II simulates project operations for a given level-of-development over a 73-year time period using a monthly time step. The level of development (land use) is held constant over the period of simulation. The inflow hydrology is based on the historic period 1922 to 1994 but modified to reflect the influence of changes in land use and upstream diversion and flow regulation in areas upstream of the model.

A new modeling language, Water Resources Engineering Simulation Language (WRESL), has been developed to serve as an interface between the user and the LP/MILP solver, time-series database, and relational database. WRESL statements describe the physical system (dams, reservoirs, channels, pumping plants, etc.), operational rules (flood-control diagrams, minimum in-stream flows, delivery requirements, etc.), and priorities for allocating water. At run-time the WRESL statements are converted to Fortran 90 code by a parser-interpreter program. After the generation of Fortran 90 code, the relational and time series data are read from separate databases and the entire problem is assembled into the proper format and passed to the solver. The MILP solver performs the necessary solution algorithms and returns the decision variable results to the time-series database. Diagnostic information from the solver this passed to the controlling user-interface and individual output files. The process involving the generated code, data access, and solver is repeated for each time period until the simulation is complete.

A new SWP and CVP south-of Delta delivery logic uses runoff forecast information and uncertainty (not perfect foresight), a delivery versus carryover risk curve, and standardized rule (Water Supply Index versus Demand Index Curve) to estimate the total water available for delivery and carryover storage. The new logic updates delivery levels monthly from January 1 through May 1 as water supply parameters become more certain.

Artificial Neural Network (ANN) routine has been developed and implemented in CALSIM-II to correlate DSM2 model-generated salinity at key locations in the Delta. The ANN flow-salinity module predicts electrical conductivity at the following three locations: Old River at Rock Slough, San Joaquin River at Jersey Point, and Sacramento River at Emmaton. Salinity is estimated based upon a time history of the following variables: Sacramento River inflow, San Joaquin River inflow, DCC gate position, and several Delta export and diversion variables. The Sacramento River inflow term combines flows from the Sacramento River at Freeport, the Yolo Bypass, and the Mokelumne, Consumnes, and Calaveras Rivers. DCC gate position is assumed to be fully open or closed. Delta exports and diversions include SWP exports at Banks Pumping Plant and North Bay Aqueduct, CVP exports at Tracy, Contra Costa Water District diversions, and net channel depletions. A total of 148 days of values of each of these parameters are included in the correlation, representing an estimate of the length of water quality "memory" in the Delta. Water quality export caps (salinity standards), generated with the monthly models ANN were imposed on the daily delta model.

3.1.1.1 Application of CALSIM-II Model to Simulate CVPIA (b)(2) and Environmental Water Account Operations

The CVPIA reallocates 800,000 acre-feet of CVP yield (600,000 acre-feet in a dry year) to restore valley fisheries. CVP yield means the delivery capability of the CVP during the 1928-1934 drought period after fishery, water quality and other flow and operational requirements have been met. The CVPIA also firmed up annual in stream supplies for the Trinity River and Central Valley wildlife refuges. The act also established an anadromous fish restoration program and an annual environmental restoration fund, financed by surcharges on CVP water and power, to mitigate for the project’s environmental impacts.

The EWA would be managed by the state and federal fisheries agencies to supplement water quality and fish protection regulations. This account could reduce conflict between the environment and water users, provide for better coordination with ecosystem restoration projects, and allow for greater protection for fish, such as the delta smelt, from entrainment at the pumps. The account could use transfers, options and/or acquisitions to obtain water to refill its storage facilities. In addition, water could be obtained through financing conservation or recycling projects.

Modeling of CVPIA (b)(2) and EWA, under the CALFED AGENCIES Framework and Record of Decision (ROD), requires layering of criteria, and accounting based upon water supply with and without particular actions. This necessitates an analysis of several annual sequential studies. (b)(2) accounting procedures require that the state of the system be known under D1485 and WQCP operations. Similarly, the south of Delta deliveries and storage to be maintained by the EWA are determined in part from the (b)(2) analysis (CVP base is directly the result of (b)(2), while the EWA receives half of the SWP (b)(2) gain). Due to the layering of constraints and operations required under the Framework/ROD, a modeling analysis has been developed to dynamically integrate four simulations from each year of the hydrologic sequence while resetting the state of the system each year to that of the final simulation. The general modeling procedure would follow the steps below:

1. Run the D1485 simulation for Oct-Sep of the current year.
2. Run the WQCP simulation for Oct-Sep of the current year.
3. Run the B2 simulation for Oct-Sep of the current year, dynamically accounting for WQCP costs and (b)(2) account balance, and implementing fish protection actions according to a preference matrix.
4. Run the EWA simulation for Oct-Sep of the current year, taking all B2 actions from (3), dynamically accounting for debt and collateral, and implementing fish protection actions according to a preference matrix.
5. Reset the state of the system for all simulations (D1485, WQCP, B2, and EWA) to that resulting from the completed EWA run. This will serve as the initial conditions for the next year’s simulations. Storage, X2, and any other variable requiring an initial state will be taken from the EWA run.
6. Repeat steps 1-5 for all years of the period of record.

Further CVPIA (b)(2) and EWA modeling work is in progress. Tables 2 and 3 show the CVPIA (b)(2) and EWA Actions.

Table 2 – CVPIA (b)(2) Actions

Action	Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	AFRP Releases (Nov. 20th, 1997)												
2	Export Reductions (150 taf)												
3	VAMP Export Restrictions												
4	VAMP Export Restrictions Extension – Post												
5	Export Ramping – EI												
6	VAMP Export Restrictions Extension – Pre												
7	Export Reduction (35 taf)												
8	Upstream Releases												

CVP

Table 3 – EWA Actions

Action	Description	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	AFRP Releases (Nov. 20th, 1997)												
2	Export Reductions – 4000 CFS for one week each month (2 weeks in Wet years)												
3	VAMP Export Restrictions												
4	VAMP Export Restrictions Extension – Pre												
5	VAMP Export Restrictions Extension – Post												
6	Export Ramping – EI												

CVP CVP/SWP

3.1.2 Monthly CALSIM-II Model Limitations

CALSIM-II simulates the entire CVP/SWP system and is focused on system wide operations. Many large areas are aggregated to simplify the model operation, this aggregation generally does not result in decreases in the reliability of model results. However, the model is not designed to evaluate relatively small projects within the Sacramento/San Joaquin River watersheds. When evaluating smaller projects, increases in the level of detail of hydrologic inputs may be required.

In any CALSIM-II modeling study, the modeled conditions in a particular year will not conform to the historic observed conditions for the same year. The purpose of the model is not to recreate historic conditions but to predict potential conditions under various system, regulatory and water demand scenarios.

The ESA limitations on Delta export pumping based on actual take limits for delta smelt and winter-run chinook salmon cannot be modeled due to lack of information on when conditions requiring export curtailments might be imposed. It was assumed that the FMWT index was always greater than the threshold value of 239.

The WQMP criteria for the limits on the concentration of organic carbon was not included in these simulation runs.

3.1.3 Daily Model development

Modeling of in-Delta storage facilities operations required a model with a daily time-step for defining the diversion and release rules. Daily time-step Delta Model was created for conducting in-Delta storage project studies. This model was used in conjunction with the CALSIM-II monthly model. The entire system's operation was simulated for one month period with the CALSIM-II monthly model and then the information on inflows to the Delta and the south-of-Delta delivery amounts was passed on to the Daily Delta Model. The Daily Delta Model then re-simulated the operations in the Delta, and the export facilities.

The monthly averaged inflows to the delta from the monthly model were converted into daily hydrographs by a utility program to pattern the monthly averaged inflows to the Delta after the historically recorded flows of the Sacramento River at Freeport, the San Joaquin river at Vernalis, a combination of the Mokelumne River at Woodbridge and the Consumnes river at Sloughhouse, and a combination of flows at the gage near Woodland, the Sacramento Weir near Bryte, and the Putah Creek near Davis. While the daily inflow hydrograph was patterned after the historically recorded inflow, the total volume of the inflow to the Delta provided by the monthly model was preserved.

After the daily operation was done, the results of the Daily Delta Model were provided to the monthly model as the initial conditions for the following month's simulation. The operation of the upstream reservoirs was re-simulated, and any gains or losses of water were reflected in the Delta outflow and the storage at San Luis Reservoir. The next month's simulation was then started with the modified end-of-month storage in San Luis Reservoir and the state of the Delta as simulated by the Daily Delta Model.

The determination of the allowable exports as a function of the salinity standards at various locations in the Delta was accomplished by providing the daily model with the monthly model's ANN estimation of the cap on total exports imposed by the controlling salinity station. This cap on the total exports would be observed every day in the current month's simulation by the daily model and the project exports would never exceed this maximum allowable rate.

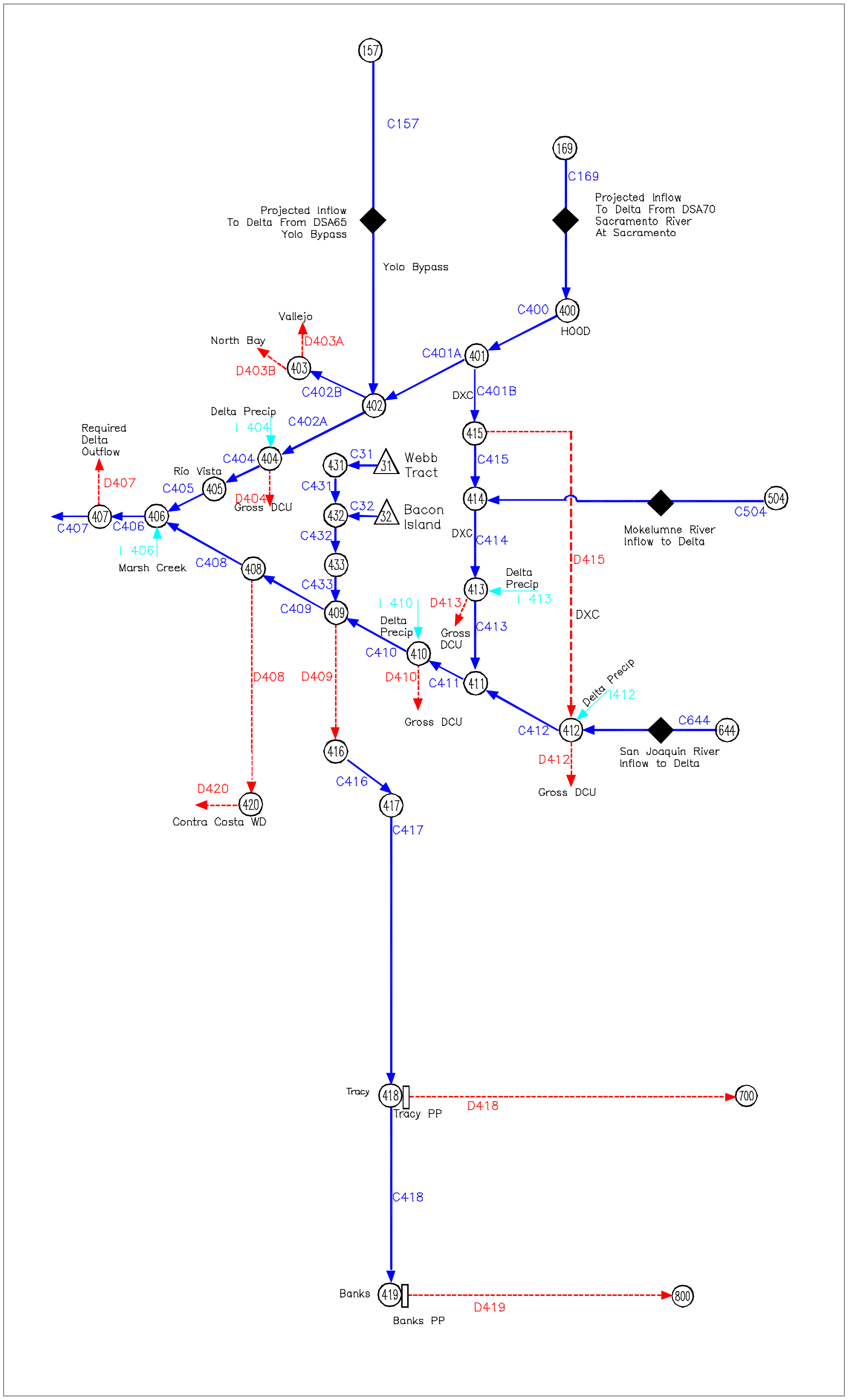
In-Delta storage project yield was maximized by adding the storage in the in-Delta facilities to the SWP portion of the San Luis Reservoir by as much vacant space as was available in the SWP San Luis Reservoir before making a computation of the Water Supply Index (WSI). The remaining portion of the storage in the In-Delta Facilities (after subtraction of the vacant space in SWP San Luis Reservoir) was added directly to the SWP delivery target every month.

To achieve the most efficient operation of the two water supply storage facilities in the with-project simulation run, the priority of filling was given to Bacon Island. This was done because the more extended period of allowable discharge from Bacon Island allowed for potential withdrawal and subsequent filling in the same year more readily, whereas the limited allowable period for discharge from Webb Tract made multiple filling in the same year practically impossible. The priority of filling in Bacon Island was achieved by assigning a higher reward for diverting the available water into the conservation storage of Bacon Island as compared to that of Webb Tract.

3.1.3.1 Changes caused by the daily Delta Operation

The key factor that induces all the changes in the daily simulation as compared to the monthly model results is the replacement of the constant monthly average inflows to the Delta by daily hydrographs. The daily variation of inflow to the Delta changes both the usable portion of the inflow and the water quality effects of the fresh water inflow. So, the water that would have been available in the monthly CALSIM-II model for export every day of the month would not necessarily be available for export in the CALSIM-II daily Delta model.

Figure 1 – Daily Delta Model Schematic showing In-Delta Storage Project Reservoirs, Webb Tract and Bacon Island as Nodes 31 and 32.



Chapter 4
OPERATION STUDIES

4.1 Introduction

The following studies were conducted using the daily CALSIM-II Model to evaluate in-Delta storage operations.

- Base case operations.
- In-Delta storage study with Webb Tract and Bacon Island as storage reservoirs with 6000 cfs maximum daily diversion to storage. This study did not have any delta smelt and DOC constraints.
- In-Delta storage study with Webb Tract and Victoria Island as storage reservoirs with 6000 cfs maximum daily diversion to storage. A 2000 cfs siphon connects Victoria Island to Clifton Court Forebay. This study did not have any delta smelt and DOC constraints.
- In-Delta storage study without delta smelt and DOC constraints.
- Delta Wetlands study with delta smelt, 1997 U.S. Fish and Wildlife Service (USFWS) Fall Mid-Water Trawl (FMWT) Index Constraints.
- Delta Wetlands study with DOC constraints.
- Impact of climate change.

Further details and results of these studies are presented in the following sections.

4.2 Base Case Operations

Base Case study simulated the existing conditions without project. Section 2.3.1 of this report describes the base case assumptions. Summary of water supply benefits and delta operations of this study are presented in Table No. 4. This table shows the 1928-34 critically dry period and the 1922-94 average period SWP/CVP contract deliveries of 3,503 taf and 5,468 TAF. For the 1922-94 average period, 56% of the total delta inflow (21,017 taf) is surplus water (i.e., 11,714 taf). About half of this water (6030 taf) is exported by SWP/CVP pumps.

4.3 In-Delta Storage Studies

4.3.1 In-Delta Storage Operations without Delta Smelt and DOC Constraints

In-Delta storage study was performed by incorporating all the operations criteria stated in the SWRCB Decision 1643, WQMP salinity constraints and fisheries Biological opinion constraints. Exceptions to this were the Fish and Wildlife FMWT index condition of less than 239 and Dissolved Organic Carbon (DOC) WQMP constraints were not used in the original DW Project Operations. All common assumptions applied to the base case also applied to the in-Delta studies. Water supply benefits are reported in Table No. 4 for the 1928-34 critically dry period and the 1922-94 average period. In-Delta storage provides export flexibility for additional water supplies to the south of Delta water users. In-Delta storage studies with Webb Tract and Bacon Island as storage reservoirs were run with maximum daily storage diversion rate of 6000 cfs. An additional long-term water supply of 126 taf is created over the base conditions. Water supply benefit for the dry period is 60 taf. The operations criteria of the biological opinion also included a constraint for mandatory release of 10% of the exported water termed as Environmental Water. Therefore, 6 taf of water supply benefit was credited to environmental benefit out of 60 taf for the Dry Period and 12 taf of water supply benefit was credited to environmental benefit out of 126 taf for the 1922-94 period. Operation of In-Delta storage reservoirs is shown in Table No. 5. With 6000 cfs maximum daily diversion to storage, total long-term average annual diversion of surplus water to Webb Tract and Bacon Island is 134 taf. During the 1928-34 critically dry period, 64 taf of water is released. Average annual release from these reservoir islands for 1922-94 period is 126 taf. Figure No. 3 shows the improvement in SWP/CVP water supply reliability with in-Delta storage. Figure No. 2 shows the storage in the reservoirs as a function of time in in-Delta storage study with 6000cfs maximum daily diversion to storage. The storage space in Webb Tract and Bacon Island will add flexibility to the SWP/CVP system by capturing operational and wet weather spills, by providing available storage capacity for water transfers, and capturing environmental flows from upstream reservoirs. In-Delta storage can be used to store EWA water. Further evaluations for environmental benefits are being done.

Table No. 4 shows the water supply benefits of In-Delta storage with Webb Tract and Victoria Island with direct connection to Clifton Court Forebay. The diversion and discharge criteria which applied to Bacon Island, applied to Victoria Island. No discharge criteria was applied to the discharge through direct connection of Victoria Island to Clifton Court Forebay. The results of this study are preliminary and further work is in progress. As shown in Table No. 5, 141 taf water is diverted into and 132 taf water is released from In-Delta Storage.

Further analysis of the Webb Tract and Bacon Island in-Delta storage study with 9000 cfs maximum daily diversion can bee seen in the Appendix. Figures 15 and 16 in the Appendix, show the end-of month storage in Webb Tract and Bacon Island. Figure 17 in the Appendix is a detailed comparison of operation between the two facilities over a 29-month period. This comparison shows that the longer period of allowable discharge from Bacon Island allows the facility to fill more than once in a water year, whereas the opportunity for multiple filling in Webb Tract is less due to its inability to discharge the stored water until July. For this reason, the priority of filling up to the conversation storage was given to Bacon Island.

Figures 18 through 20 in the Appendix, show the changes in annual deliveries to SWP south-of Delta contractors, the interruptible deliveries made by SWP, and the CVP south-of -Delta contractors. The changes in the end-of-month storage in the key reservoirs of the system induced by the operation of the in-Delta storage facilities are shown in Figures 21 through 25 in the Appendix.

Table 4 – Comparison of Exports and Deliveries of the Base and In-Delta Storage Studies
(All units in taf)

Studies	SWP/CVP Contract Deliveries		SWP Interrruptible Deliveries		SWP/CVP Deliveries with Interrputables		Total Delta Exports (SWP+CVP)		Total Delta Inflow		Minimum Required Delta Outflow		Delta Surplus		Total Delta Outflow	
	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg	Dry Period Avg	73-Yrs Avg
Base Study 1	3,503	5,468	35	151	3,538	5,619	3,646	6,030	10,190	21,017	3,004	2,390	2,420	11,714	5,424	14,104
In-Delta Storage Study (Webb Tract & Bacon Island as Storage Reservoirs with 6000 cfs maximum diversion to Storage)	3,580	5,577	36	168	3,616	5,745	3,726	6,156	10,210	21,018	3,032	2,394	2,364	11,573	5,396	13,967
Difference (In-Delta storage Study -minus- Base Study)	77	109	1	17	78	126	80	126	20	1	28	4	-56	-141	-28	-137
In-Delta Storage Study (Webb Tract & Victoria Island as Storage Reservoirs with 6000 cfs maximum diversion to Storage)	3,516	5,570	49	172	3,565	5,742	3,682	6,155	10,201	21,017	3,007	2,393	2,409	11,577	5,416	13,970
Difference (In-Delta storage Study -minus- Base Study)	13	102	14	21	27	123	36	125	11	0	3	3	-11	-137	-8	-134

Figure 2 – Webb Tract and Bacon Island Storage Frequency

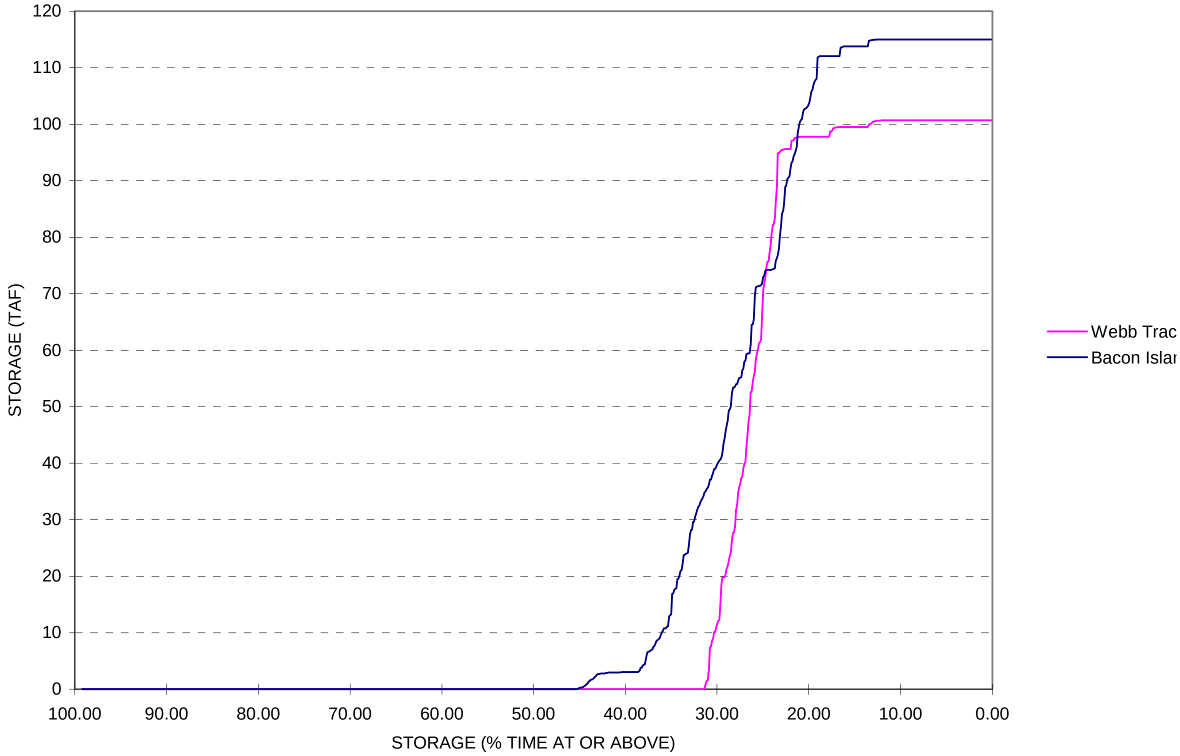


Figure 3 – SWP/CVP Supply Reliability

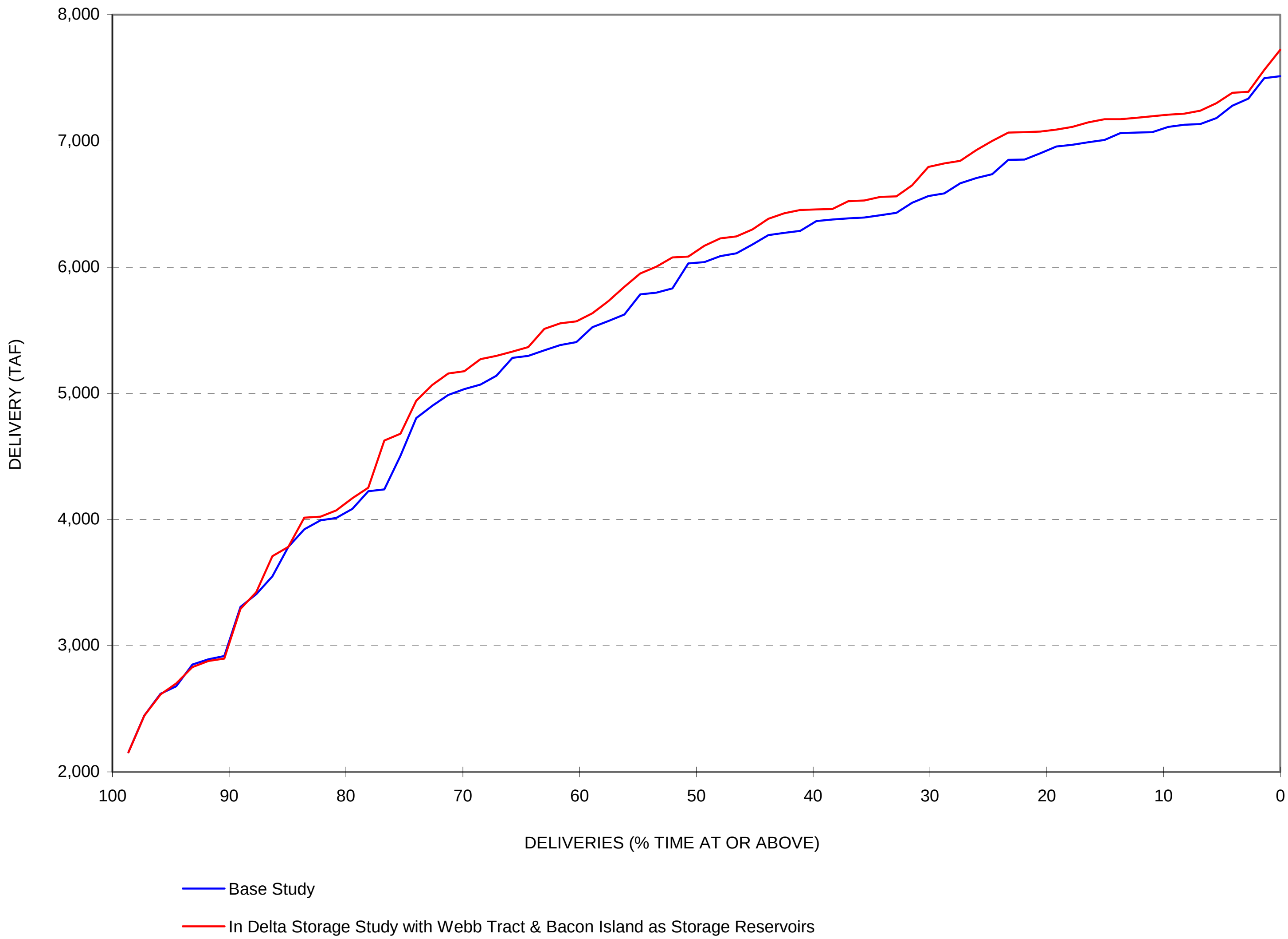


Table 5 – In-Delta Storage Operations
(All units in taf)

Study	Reservoir	Diversion to Reservoir		Release from Reservoir	
		Dry Period Avg.	73-Yrs Avg	Dry Period Avg.	73-Yrs Avg
Webb Tract & Bacon Island as Storage Reservoirs with 6000 cfs maximum diversion to Storage	Webb Tract	8	56	24	53
	Bacon Island	21	78	40	73
	Total	29	134	64	126
Webb Tract & Victoria Island as Storage Reservoirs with 6000 cfs maximum diversion to Storage	Webb Tract	6	54	23	50
	Victoria Island	27	87	31	82
	Total	33	141	54	132

4.3.2 In-Delta Storage Study with Delta Smelt Constraints

Additional restrictions apply if the Fall Mid Water Trawl (FMWT) index shows a significant decline in delta smelt abundance. This index is developed for each year based on delta smelt abundance during the months from September to December. These restrictions apply if the index shows a significant decline in delta smelt abundance. This criterion was not applied in the original DW study. Monthly restrictions on diversions are stated in the operations criteria based on FMWT. No diversions can be made from February 15 to the end of June if FMWT is less than 239. FMWT Index data is available from 1967 to 1994. Data indicates there are 8 years during this period when the FMWT index is lower than 239. The criteria provide for a higher partial value of FMWT if it is available before its final calculation in December.

The comparison of this study with in-Delta storage study without these constraints for the time period of 1975-1991 is given in Table No. 6. This FMWT Index criterion decreases the average annual delivery by 20 taf. To see a true impact of this criteria a probability analysis should be conducted for 73 years period. There is need to hold further discussions on the fisheries criteria application in light of DW Project being included as a CALFED AGENCIES Project.

4.3.3 In-Delta Storage Study with DOC Constraints

Water Quality Management Plan (WQMP) criteria limit releases from in-Delta storage if the DOC value at the urban intakes exceeds 4 mg/l. These preliminary studies were conducted for a period of 1975 to 1991 as the source water DOC information was available only for this period. Results of the DW study without DOC constraints were used as input to the DSM2 model to determine WQMP DOC constraint compliance at the urban intakes. Water quality modeling showed DOC standards were exceeded at the urban intakes. In order to comply with the WQMP criteria, the CALSIM-II model was modified to include additional water quality rules for releases from the Webb Tract and Bacon Island Reservoirs. CALSIM-II studies were conducted with two Asymptote (A) DOC values of 70mg/l and 215mg/l. These values represent DOC at the two feet reservoir levels and depending on the depth of the reservoir, DOC changes. With Depth higher than 2 feet, DOC value will decrease. A 20 feet depth reservoir will represent a low bookend DOC value of 6.76 mg/L for Asymptote equal to 70mg/ l. Similarly, a 20 feet depth of water in the reservoir will represent a high bookend DOC value of 20.77 mg/l for a 215mg/l

Asymptote value. Two CALSIM-II modeling studies with low and high bookend DOC values were conducted. Table No. 6 shows the results of these studies. Low bookend DOC constraint doesn't reduce the Project yield when compared to the base. For the high bookend DOC value, the average annual delivery is reduced by 16 taf.

Any water available as a result of water quality restrictions will be credited to meet the EWA and CVPIA requirements. Further studies are required to assess CVPIA and EWA benefits in detail.

Table 6 – Impact of Delta Smelt (FMWT Index<239) and DOC Water Constraints on SWP/CVP Water Supplies
(All units in taf)

CALSIM Studies (Study Period 1975-1991)	Total SWP/CVP Average Annual Delivery	Difference in Average Annual Delivery from Base
In-Delta Storage Study w/o Delta Smelt FMWT<239 and DOC	103	----
In-Delta Storage Study with Delta Smelt FMWT<239	83	20
In-Delta Storage Study with Low Bookend DOC (Asymptote DOC value =70mg/L)	103	0
In-Delta Storage Study with High Bookend DOC (Asymptote DOC value =215mg/L)	87	16

As shown in Table 6, the high bookend DOC constraints reduce project yield by a yearly average 16 TAF over the period WY1975-WY1991. During the same period, it is shown that the low bookend DOC constraints have no effect on project yield. However, the effect of the DOC constraints on yearly average island discharge is much more significant. While yearly average island discharge with no DOC constraints is 102 TAF (roughly equivalent to the project yield of 103 TAF), the island discharge with high and low bookend DOC constraints is 69 TAF and 94 TAF, respectively. As such, with the high and low DOC constraints, the ratio of project yield to island discharge is 1.3:1 and 1.1:1, respectively. So what is the project benefiting from other than island discharge when the DOC constraints are applied?

The primary difference in operation caused by the DOC constraints is that significant quantities of island storage are carried over from one year to the next, whereas without DOC constraints, the islands completely discharge all diverted water in the same year. As such, during dry periods, the islands operated with the DOC constraints contain water carried over from the previous year while the islands operated without the DOC constraints sit empty. With more water, more risk is taken in allocating deliveries during the dry period; this results in a reduction of Oroville storage as compared to the base study. Overall, the impact to project yield ends up being greater than the quantity of water discharged from the islands. Therefore, as the model is presently running, the forced carryover of storage by the DOC constraints significantly softens the effects of the constraints on project yield, at least in the 16 years that the analysis has been performed. As a result, the present model is likely overestimating project yield when the DOC constraints are applied.

With respect to the above analysis, the usability of carryover storage must be addressed. Is it reasonable to expect water that has been held on the islands for one or more years to be suitable for discharge? Changes in the model might be necessary to dispense of water after a given period of retention.

4.3.4 Climate Change Impact Evaluation

Global warming and rise in sea level may add additional constraints on the operations. There may be changes in hydrological patterns of flows due to changes in precipitation. During winter, rains over snow may cause flash flooding in the upstream head reaches and thus winter flows may be higher than current conditions. Also, it will cause less snow cover on ground and less late spring runoff. The DWR Flood Management Division made an assessment of flow variations as a result of climate change. A preliminary monthly hydrology was developed with altered patterns of reservoir inflows in the upper San Joaquin River and the Sacramento River watersheds. This study is more of a sensitivity analysis and results should be considered as preliminary. This hydrology was used to determine the impact of climate change on project yield. CALSIM-II monthly Model used this hydrology as input and converted it into daily flows for the daily delta model. A new base study and a Delta Storage were created with this hydrology. The Climate change CALSIM-II study was conducted for a time period of 1922-69. Results of in-Delta operation in these modeling studies are presented in Table No. 7. Climate change creates more surplus water in the delta for in-Delta storage to capture. Without the climate change, 10,666 taf/yr of surplus is created for the period of 1922-69. With the Climate change, 10,680 taf/yr of surplus is created. This creates 14 taf more surplus water for diversion into in-Delta storage. However, all this water was not diverted to Webb Tract and Bacon Islands due to diversion constraints. The climate change study also shows higher storages in north of delta reservoirs which can be used to fill downstream in-Delta storage.

Table 7 – Impact of Climate Change on In-Delta Storage Operations
(All units in taf)

Reservoirs	In-Delta Storage Study without Climate Change impact on flows	In-Delta Storage Study with Climate Change impact on flows	Net Impact due to Change in Flow Patterns
Delta Surplus	10,666	10,680	+14
<u>Diversions</u>			
Webb Tract	54	60	
Bacon Island	76	75	
Total Diversions	130	135	+5
<u>Releases</u>			
Webb Tract	50	55	
Bacon Island	71	69	
Total Releases	121	124	+3

APPENDICES

APPENDIX A

MEMORANDUM REPORT

To: Tirath P. Sandhu
In-Delta Storage Facilities
Integrated Storage Investigations

Date: November 29, 2001

From: Sushil K. Arora
Hydrology and Operations
Modeling Support Branch

Subject: CALSIM Model Runs; In-Delta Storage Facilities

This supersedes the memorandum report of November 14, 2001 on the IDS modeling studies. Attached is the updated results of the simulation runs completed last week. These updated simulation runs were conducted to correct some of the minor problems that we observed after a detailed examination of the original simulation results. For these simulation runs, CALSIM code was modified to correct the unreasonable fluctuations in the SWP monthly deliveries that we observed in the original runs, occasionally. Although infrequent and inconsequential as to their effect on the overall result, we felt that the problem had to be corrected. The technical details of the code modifications will be documented in a separate technical report. If you have any comments or questions contact me at 653-7921, Sina Darabzand at 653-9648, or Dan Easton at 653-7695.

Introduction

The operation studies documented in this report were conducted to independently verify the results of the studies done by the Delta Wetlands Corporation with a model that more accurately simulated the operation of the In-Delta storage facilities. The operation of these facilities would affect the Delta water supply, the operation of the CVP and SWP export facilities, the hydrodynamics of the Delta channels as the allowable portion of the surplus Delta outflow is diverted into storage, as well as Delta water quality as these storage facilities release the impounded water for export into the Delta channels.

To assess the operational flexibility and water supply benefits of the project more accurately a new Daily Delta CALSIM model of the estuary and the CVP and SWP export and conveyance facilities south of the Delta was developed. This model utilized daily input hydrographs as inflow to the Delta and was coupled with a monthly time step simulation, SWP/CVP system model, CALSIM-II. A brief discussion of the modeling methodology is presented later in this report.

Water quality restrictions on the Projects' exports out of the Delta was estimated by the Artificial Neural Network (ANN) model that was based on a correlation between the monthly inflows to the Delta and electrical conductivity (EC) at four critical stations. The hydrodynamics and water quality impacts of the In-Delta storage facilities is assessed later by using the results of these operation studies as input to the DWR Delta Simulation Model (DWRDSM2) and will be documented in a separate report.

The base simulation run in these studies incorporated the provisions of the SWRCB Water Rights Decision 1641 as documented in the Draft Water Quality Control Plan for the San Francisco Bay / Sacramento-San Joaquin Delta Estuary, May 1995. The In-Delta Storage Facilities that were incorporated in the with-project study was similar to the configuration used in the operation studies conducted by the Delta Wetlands. A list of studies with their references as used in this report follows.

Study 1 : The CALSIM-II monthly simulation model of the base system.

Study 2 : The final compilation of the results in the monthly module of the combined daily-monthly base simulation run.

Study 3 : The daily compilation of the results in the Daily Delta module of the combined daily-monthly base simulation run.

Study 4 : The final compilation of the results in the monthly module of the combined daily-monthly with-project simulation run.

Study 5 : The daily compilation of the results in the Daily Delta module of the combined daily-monthly base simulation run.

As shown in Figure 1 the In-Delta Storage Facilities included the two water supply storage facilities, Webb Tract and Bacon Island, and the two islands operated as waterfowl habitat and permanent wetlands for environmental benefits, Bouldin Island and Holland Tract. Operation of the habitat islands was considered only as far as they affected the maximum allowable diversion quantities into the storage islands. It was assumed that the diversions into the habitat islands were accounted for as a part of the Delta's consumptive use computations and were covered under Delta Wetlands' prior water rights for these islands. Figure 2 shows the schematic used in the daily Delta model.

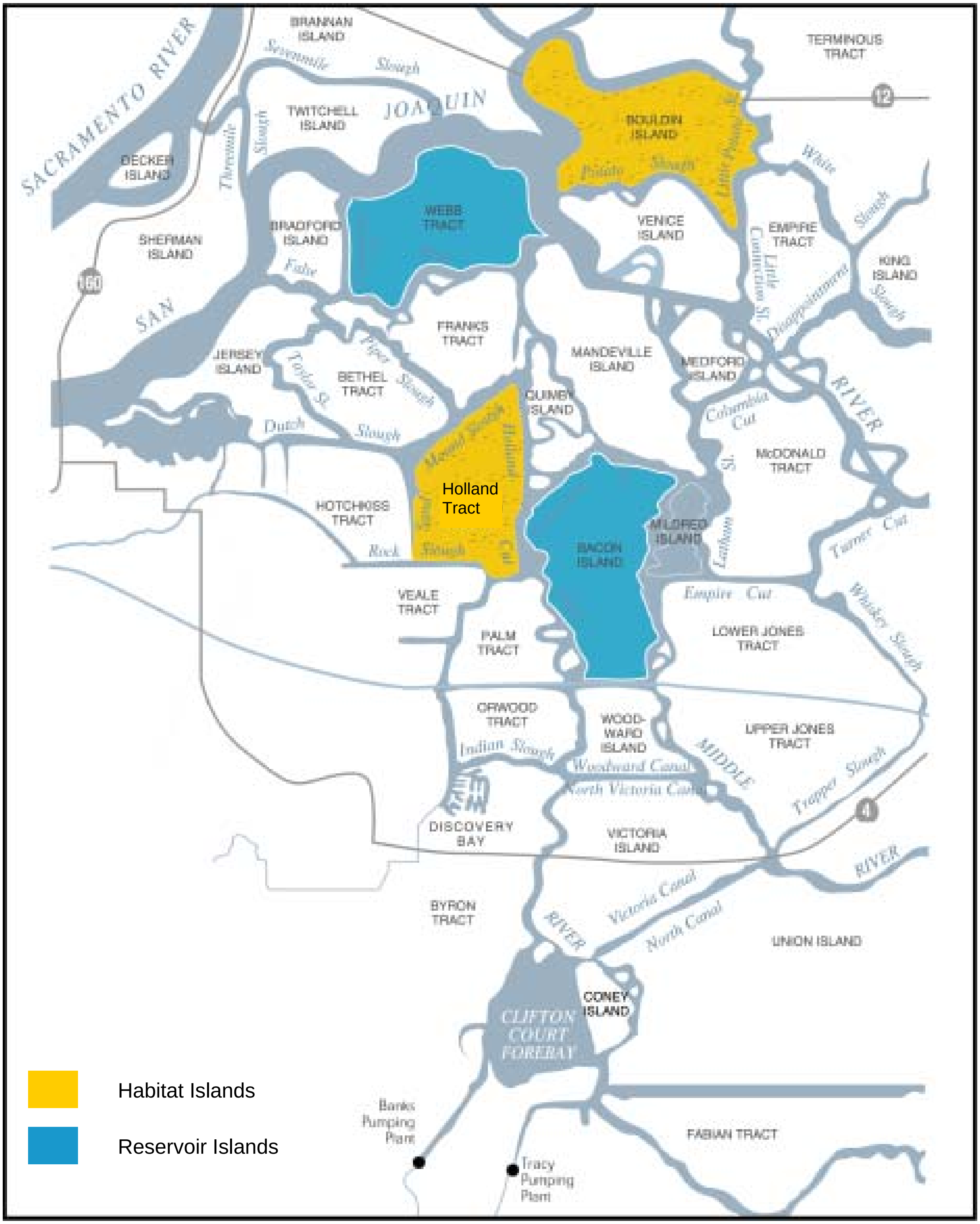
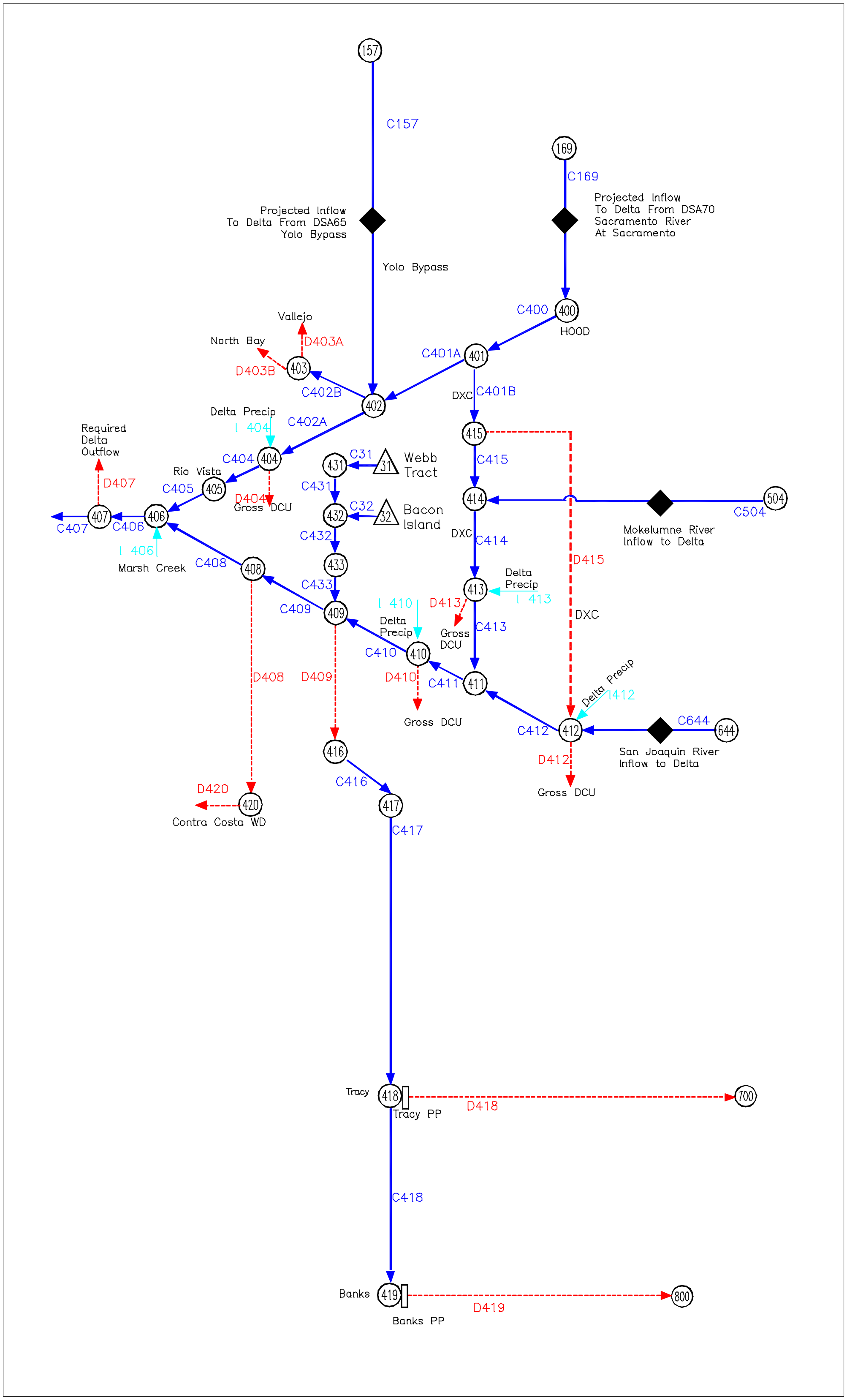

SACRAMENTO RIVER
BRANNAN ISLAND
Sevenmile Slough
TWITCHELL ISLAND
JOAQUIN
SAN
DECKER ISLAND
Threemile Slough
SHERMAN ISLAND
160
BRADFORD ISLAND
False
WEBB TRACT
BOULDIN ISLAND
Potato Slough
Little Potato Sl.
TERMINOUS TRACT
12
White Slough
VENICE ISLAND
EMPIRE TRACT
Little Connection Sl.
KING ISLAND
Slough
Disappointment
FRANKS TRACT
MANDEVILLE ISLAND
MEDFORD ISLAND
JERSEY ISLAND
Taylor Sl.
BETHEL TRACT
Piper Slough
Dutch Slough
QUIMBY ISLAND
Columbia Cut
RIVER
Mound Slough
Holland Cut
Holland Tract
Sand Mound Slough
McDONALD TRACT
HOTCHKISS TRACT
Rock Slough
MILDRED ISLAND
BACON ISLAND
Latham Sl.
Turner Cut
VEALE TRACT
Empire Cut
Whiskey Slough
PALM TRACT
LOWER JONES TRACT
ORWOOD TRACT
Indian Slough
WOODWARD ISLAND
Woodward Canal
North Victoria Canal
MIDDLE
UPPER JONES TRACT
Trapper Slough
4
DISCOVERY BAY
VICTORIA ISLAND
RIVER
BYRON TRACT
Victoria Canal
North Canal
RIVER
UNION ISLAND
CLIFTON COURT FOREBAY
CONEY ISLAND
Banks Pumping Plant
Tracy Pumping Plant
FABIAN TRACT
Habitat Islands
Reservoir Islands

Figure 2 – Daily Delta Model Schematic



Major Assumptions

Base Study

Level of development and demands

- 2020 Level of development and upstream depletions (hydrologic input d09c).

- 2020 level of demands.

    - Total SWP entitlement demands from 3.4 MAF to 4.2 MAF/year, depending on the wetness index. Maximum SWP interruptible demands at 134 TAF/month.

    - Total south of Delta CVP demands, without the demands in the Cross Valley Canal's service area, at 3.3 MAF/year including Level II Refuge demand of 288 TAF/year.

    - Cross Valley Canal demands at 128 TAF/year.

Delta outflow standards

- The minimum required outflow standards in the Sacramento-San Joaquin Delta set by the SWRCB Water Rights Decision 1641 as follows (see Table 1):

    - The minimum monthly average Net Delta Outflow Index (NDOI) for January from 4,500 cfs to 6,000 cfs, depending on the Eight River Index for December.

    - The minimum monthly average NDOI for the period of February to June determined by the flows required to maintain the 2ppt isohaline line (X2 line) at the appropriate distance from the Golden Gate Bridge as prescribed by the WQCP of May 1995.

    - The minimum monthly average NDOI for July from 4,000 cfs to 8,000 cfs, depending on the year type.

    - The minimum monthly average NDOI for August from 3,000 cfs to 4,000 cfs, depending on the year type.

    - The minimum monthly average NDOI for September constant for all year types at 3,000 cfs.

    - The minimum monthly average NDOI for October from 3,000 cfs to 4,000 cfs depending on the year type.

    - The minimum monthly average NDOI for November and December from 3,500 cfs to 4,500 cfs depending on the year type.

Stream flow standards

- Minimum flows below Keswick in the period of April through September in accordance with the 1993 Biological Opinion by the NMFS at 5,500 cfs to 11,000 cfs in most years and reduced to 3,750 cfs to 7,125 cfs in drier years.

- Trinity River Minimum Fish flows below Lewiston Dam at 369-815 TAF/year, depending on the Trinity River Index.

- The minimum monthly average flow in the Sacramento River at Rio Vista from 3,000 cfs to 4,500 cfs, depending on the month and year type.

- Stanislaus River operations in accordance with the USBR's New Melones Interim Operation Plan.

- The minimum monthly average flow in San Joaquin River at Vernalis was only met during the period of April 15 to May 15 as prescribed by the Vernalis Adaptive Management Plan (VAMP).

Project Pumping and conveyance capacities

- Banks pumping capacity at 10,300 cfs without restrictions.

- Tracy pumping capacity at 4,600 cfs limited by the downstream aqueduct capacity.

- Wheeling for CVP by SWP to meet the Cross Valley Canal demands of up to 128 TAF/Year when excess pumping capacity was available at Banks Pumping Plant, SWP portion of San Luis Reservoir was full, and all SWP entitlement demands.

- Joint Point of Diversion to provide unlimited wheeling for CVP by SWP when excess pumping capacity was available at Banks Pumping Plant, SWP portion of San Luis Reservoir was full, and all SWP demands, including the interruptible demands were met.

Limits on the allowable exports

- Maximum 3-day running average of the combined exports at both projects pumping facilities from April 15 to May 15 limited to the greater of the 3-day running average of the San Joaquin River flows at Vernalis or 1,500 cfs.

- Maximum 3-day running average of the combined exports at both projects pumping facilities from February to June (except for the April-May constraint above) limited to 35% to 45% of the 3-day running average of the total Delta inflow, depending on January's Eight River Index.

- Maximum 3-day running average of the combined exports at both projects pumping facilities from July to January limited to 65% of the 3-day running average of the total Delta inflow.

Delta Cross Channel gates

- DXC gates closed for 45 days during November to January, all of February through May, and 4 days during June.

- Flow through Georgiana Slough and DXC a function of the Cross Channel gates position, flows in the Sacramento River, the Eastside Streams, and the Yolo Bypass.

With-Project Study

The modeling assumptions for this study include all the assumptions for the above **Base Study**, plus the following Criteria for the operation of the In-Delta Storage Facilities:

- Diversion Criteria (see Table 2)

  - Delta Wetlands diversion to storage could only occur when the volume of allowable water for export (i.e., the lesser of the amount specified by the export limits and the amount of available water) is greater than the actual pumping at Banks and Tracy Pumping Plants. This would occur under the following conditions:

    - All Delta outflow requirements are met.

    - Export limit is greater than the actual pumping at banks and Tracy P.P. when they are pumping at or below the physical pumping capacities as allowed by the Corps Permit such that water that is allowable for export is not being exported by Banks and Tracy P.P.

  - Initial diversions to DWP shall not be made for the current water year (commencing October 1) until X2 has been west of Chipps Island (75 km upstream of the Golden Gate Bridge) for a period of ten (10) consecutive days. After initial X2 condition is met, diversions shall be limited to a combined maximum rate of 5,500 cfs for five (5) consecutive days.

  - Maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cfs (9 taf/day). The combined maximum daily average rate of diversion for all islands (including diversions to habitat islands) will not exceed 9,000 cfs.

  - The maximum annual amount diverted to Webb Tract storage shall not exceed 155 taf per year from January 1 to March 31 and June 1 to December 31 and shall not exceed 106,900 af per year from December 15 to March 31. The total amount of water taken from all sources shall not exceed 417 taf per water year of October 1 to September 30.

  - The maximum annual amount diverted to Bacon Island storage shall not exceed 147 taf per year from January 1 to March 31 and June 1 to December 31 and shall not exceed 110,570 af from December 15 to March 31. The total amount of water taken from all sources shall not exceed 405 taf per water year of October 1 to September 30.

Table 2 – Operation Criteria for In-Delta Storage

CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FLOW STANDARDS												
*** DIVERSION TO STORAGE** [1]												
D1643 Diversion Criteria												
No Diversion to Storage												
Initial Delay Period-X2 days past Chipps (75km)		10 days								10 days		
Initial Ramping Period -5,500 cfs max		5 days								5 days		
Min 14-day running avg of X2 requirement				X2 < 75 km								
Min 14-day running avg of X2 requirement	X2 < 81 km						X2 < 81 km					
Min 14-day running avg of X2 requirement when delta smelt are present at CCWD intake.												X2 < 81 km
Proj. Div is 500 cfs if 14-day running avg of X2		81 <X2 >80 km							81 <X2 >80 km			
Project Div is 1,000 cfs if 14-day running avg of X2		X2 >81 km							X2 >81 km			
Maximum allowable X2 shift (location)		2.5 km								2.5 km		
Limit on % of Net Delta Outflow	15 %	15 %	15 %	0 %	0 %	25 %	25 %	25 %	25 %	25 %	25 %	25 %
Max. Annual Diversion to Storage					Webb Tract -262 taf/year, Bacon Island - 258 taf/year							
Biological Opinion Diversion Criteria												
Initial Diversion for Water Year		X2 < 74 km								X2 < 74 km		
Minimum X2 requirement (location)		X2 < 81 km								X2 < 81 km		
Limit on % of surplus water	90 %	75 %	50 %	0 %	0 %	50 %	75 %	90 %	90 %	90 %	90 %	90 %
Limit on % of SJR - 15 days per month	125 %	125 %	50 %									125 %
Limit Diversions during DXC Closure												
Limit Div to 550 cfs unless QWEST remains +ve												
Maximum Top-Off Diversion Rate [2]						215 cfs	270 cfs	200 cfs	100 cfs	33 cfs		
Reduce Diversion to 50% of previous days diversion rate if Delta Smelt are present												
*** DISCHARGE FOR EXPORT** [3]												
D1643 Discharge Criteria												
Webb Tract (max 2,000 cfs)												
Fixed prohibitions				No discharges for export								
Limit on % of available export capacity							75 %					
Bacon Island (max 4,000 cfs)												
Limit on % of SJR inflow				50 %	50 %	50 %						
Limit on % of available export capacity		75 %	50 %	50 %	50 %	50 %	75 %					
Max. Chloride conc. Increase at CCWD intake						10 mg/l 14-day running average						
Zero salinity increase if it is already exceeding 90% of standard.												
Max. Annual Release of Stored Water						822 taf / year						
Max. Annual Export of Stored Water						250 taf / year						
Biological Opinion Discharge Criteria												
Reserved Environmental Water [4]	10 %	10 %	10 %	10 %	10 %	10 %						10 %
Limit Discharge for export to 50% of previous days diversion if Delta Smelt are present												

Footnotes

[1] Maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cfs. The combined maximum daily average rate of diversion for all islands (including 200 cfs diversions to each of the habitat islands) will not exceed 9,000 cfs.

[2] Water will be diverted onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, referred to as topping-off reservoirs. The maximum topping-off diversion rates shall be reduced by an amount equal to the habitat island diversions during the same period.

[3] Discharges will be pumped at a combined maximum daily average rate of 6,000 cfs. Discharge is subjected to export limits, treated as an export in the monthly E/I ratio computation except when water is discharged for environmental water account.

[4] A quantity of "environmental water" will be provided for release as additional Delta outflow equal to 10% of all discharges for export that occur in the period of December thru June.

- Diversions shall not exceed 1000 cfs when the 14-day running average of X2 is farther than 80 km upstream of the Golden Gate Bridge, nor exceed 500 cfs if the 14-day running average of X2 is farther than 81 km upstream of the Golden Gate Bridge.

- No Diversions to storage will be made if the Delta is in excess conditions and such diversions cause the location of the 14-day running average of X2 to shift upstream (east) such that X2 is:

  - East of Chipps Island (75 river kilometers upstream of the Golden Gate Bridge) during the months of February through May, or
  - East of Collinsville (81 kilometers upstream of the Golden Gate Bridge) during the months of December, January, June, July, and August.

- In the period from September through March DW shall not divert water to storage when X2 is located upstream of Collinsville salinity gauge.

- In the period from October through March, Delta Wetlands shall not divert water to storage if the effect of Delta Wetlands diversions would cause an upstream shift in the X2 position in excess of 2.5 km (i.e., increase the X2 by 2.5 km).

- In the period from April through May, Delta Wetlands shall not divert water to storage (assume FMWT Index > 239).

- Delta Wetlands diversions to storage shall not exceed the following percentage of the available surplus water (assume FMWT Index > 239 scenario):

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Percent	90%	90%	90%	90%	75%	50%	0%	0%	50%	75%	90%	90%

- Delta Wetlands diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate (assume FMWT Index > 239 scenario):

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Percent	25%	25%	25%	15%	15%	15%	0%	0%	25%	25%	25%	25%

- In the period from December through March, Delta Wetlands Diversions to storage shall not exceed the percentage of the previous days San Joaquin River inflow rate. Assume this limit applies 15 days per month in December through March whenever Delta Wetlands diverts water to storage (assume FMWT Index > 239 scenario):

Month	DEC	JAN	FEB	MAR
Percent	125%	125%	125%	50%

- Diversion to DW shall be reduced to 550 cfs unless QWEST remains positive.

- In the period from November through January, when the Delta Cross Channel gates are closed, Delta Wetlands shall limit diversions to storage as follows:

Delta Inflow	Max. combined Diversion Rate
<=30,000 cfs	3,000 cfs
<=50,000 cfs	4,000 cfs

- Water will be diverted onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, referred to as "topping-off" reservoirs. Topping-off diversions shall not exceed the following maximum diversion rate (cfs) and maximum monthly quantity (taf) listed below:

Month	JUN	JUL	AUG	SEP	OCT
Maximum diversion rate (cfs)	215	270	200	100	33
Maximum monthly quantity (taf)	13	16	12	6	2

  The maximum topping-off diversion rates shown above shall be further limited by diversions onto the habitat islands. The maximum topping-off diversion rate and quantity shall be reduced by an amount equal to the habitat island diversions during the same period.

- The maximum rate of proposed diversion onto Holland Tract and Bouldin Island will be 200 cfs per island. Diversions onto the habitat islands will not cause the combined daily average maximum diversion rate of 9,000 cfs for all four project islands to be exceeded. Water will be applied in each month of the year

- Discharge Criteria (see Table 2)

  - Discharges will be pumped at a combined maximum daily average of 6,000 cfs. Combined monthly average reservoir island discharge will be up to 4,000 cfs. Maximum annual release of stored water would be 822 taf.

  - Maximum Annual export of stored water would be 250 taf.

  - No discharge shall be made for export from Webb Tract from January through June.

  - In the period from April through June, DW shall limit discharges for export from Bacon Island to one-half (50%) of the San Joaquin inflow measured at Vernalis.

  - DW shall not discharge for export any water from the habitat islands.

  - Delta Wetlands discharge is subject to export limits, treated as an export in the monthly E/I ratio computation.

  - In the period from February through July, DW discharges for export shall be limited to the following percentage of the available unused export capacity at the CVP and SWP facilities:

Month	FEB	MAR	APR	MAY	JUN	JUL
Percent (Bacon Island)	75%	50%	50%	50%	50%	75%
Percent (Webb Tract)	NA	NA	NA	NA	NA	75%

- Storage

  - Storage capacity of reservoir Islands

Webb Tract	100,700 acre-feet
Bacon Island	115,000 acre-feet

  - Storage Levels in the reservoir Islands (TAF)

Webb Tract	L1= 1.4	L2= 36.6	L3= 71.8	L4=100.7	L5=100.7
Bacon Island	L1= 1.2	L2= 37.7	L3= 74.2	L4=115.0	L5=115.0

Modeling Methodology

The accurate modeling of the In-Delta Storage Facilities operation required a model with a daily time-step that could capture the intent of the diversion and discharge rules spelled out in the SWRCB's Water Rights permits issued to the Delta Wetlands. Many of the rules allowing diversions into the storage facilities or discharge into the Delta channels required daily accounting and tracking of various water quality and flow parameters in the Delta and at the export facilities. For this purpose, a model of the Delta and the CVP and SWP export and conveyance facilities south of the Delta was constructed with a daily time step. This model was coupled with CALSIM-II monthly model in such a way that the monthly model would first simulate the entire system's operation for a one-month period. A selected set of variables from the monthly model simulation was then passed on to the daily model for a more detailed and accurate simulation of the operations in the Delta, at the export facilities, and along the CVP and SWP conveyance facilities south of the Delta.

Conversion Routine

The first step in the simulation of the daily model was to convert the averaged inflows to the Delta computed by the monthly model into daily hydrographs. For this purpose, a utility program was constructed to pattern the monthly averaged flows in the Sacramento River (C169), the San Joaquin River (C644), the Eastside Streams (C504), and the Yolo Bypass inflow (C157) after the historically recorded flows of the Sacramento River at Freeport, the San Joaquin River at Vernalis, a combination of the Mokelumne River at Woodbridge and the Cosumnes River at Sloughhouse, and a combination of flows at the gage near Woodland, the Sacramento Weir near Bryte, and the Putah Creek near Davis. While the daily inflow hydrograph was patterned after the historically recorded inflow, the total volume of the inflow to the Delta provided by the monthly model was preserved.

Daily Model Resimulation

With the daily hydrographs provided by the conversion routine, the daily model would then resimulate the operation of the export facilities based on the availability of the exportable water as a result of the daily simulation of inflows and after meeting the various flow and water quality standards in the Delta. The daily simulation made it possible to model many of the standards of the 1995 WQCP much more accurately, as they required 3-day or 14-day running average provisions. Additionally, the operation of the In-Delta Storage Facilities required daily tracking of the X2 position as well as other parameters related to the export of water released from these facilities.

To achieve the required mass balance between the monthly and the daily models, the variations from the monthly model's simulation was reflected in the modified operation of the export facilities, the outflow from the Delta, and the storage in SAN Luis Reservoir. The results of the daily operation, and particularly the ending storage in San Luis Reservoir was provided to the monthly model as the initial conditions for the following month's simulation. The monthly model did not resimulate the operation of the upstream reservoirs to reflect any of the changes in operation from the daily simulation. It would simply start the next month's simulation with the end-of-month storage in San Luis Reservoir and the state of the Delta as simulated by the daily model.

Water Quality Export Caps

The determination of the allowable exports as a function of the salinity standards at various locations in the Delta was accomplished by providing the daily model with the monthly model's ANN estimation of the cap on total exports imposed by the controlling salinity station. This cap on the total exports would be observed by the daily model every day in the current month's simulation, and the project exports would never exceed this maximum allowable rate.

Maximizing Project Yield

In order to maximize the potential contributions of the In-Delta Storage Facilities to the system's delivery capability the water stored in the islands were used to increase deliveries over the base system every year. This was accomplished by adding the storage in the In-Delta Facilities to the SWP portion of San Luis by as much vacant space as was available in SWP San Luis before making a computation of the Water Supply Index (WSI). Moreover, the remaining portion of the storage in the In-Delta Facilities (after subtraction of the vacant space in SWP San Luis) was added directly to the SWP delivery target every month.

Coordinated Operation

In order to achieve the most efficient operation of the two water supply storage facilities the priority of filling was given to Bacon Island. This was done because the more extended period of allowable discharge from Bacon Island allowed for potential withdrawal and subsequent filling in the same year more readily, whereas the limited allowable period for discharge from Webb Tract made multiple filling in the same year practically impossible. The priority of filling in Bacon Island was achieved by assigning a higher reward for diverting the available water into the conservation storage of Bacon Island as compared to that of Webb Tract.

Summary of Results

This section is divided into two separate headings. Under the first heading, the changes in the system's performance caused by the daily operation of the Delta are summarized. These changes are shown as differences in the annual deliveries, total Delta exports, and end-of-month storages in the key storage facilities of the system. Under the second heading, the contributions of the In-Delta Storage Facilities to the enhancement of the system's delivery capability, as well as some of the details of the In-Delta Storage Facilities operation, and the changes in other key parameters of the system are summarized.

Changes Caused by the Daily Operation

The key factor that induces all the other changes in the daily simulation as compared to the monthly model results is the replacement of the constant monthly averaged inflow to the Delta by daily hydrographs. The daily variation of inflow to the Delta changes both the usable portion of the inflow and the water quality effects of the fresh water inflow. As far as the water supply effects of the operation are concerned the water that would have been available in the monthly model for export every day of the month would not necessarily be available for export in the daily model. Some days in the month the inflow would be much higher than the average monthly inflow, which although beneficial in improving water quality by increasing the fresh water gradient, may not be within the range of allowable exports, and therefore, flow out of the Delta as additional surplus Delta outflow. And then, there would be days that the daily inflow would be much less than the monthly average inflow with a resulting lower export. Typical changes in the total Delta inflow, total exports, and the net Delta outflow resulting from the more refined daily operation are presented in Figures 3 through 5. The daily fluctuations of inflow above and below the monthly mean cause a diversion pattern that reduces the exports from the Delta as compared to those achieved in the monthly model. This phenomenon is shown in Figure 6, where the monthly average amounts exported by the daily model are shown to be consistently lower than those in the monthly model, except for August. The lower exports inevitably impact on the annual deliveries. Figures 7 through 9 compare the annual deliveries between the daily and the monthly simulation runs, Studies 1 and 2, respectively. The changes in the end-of-month storage amounts in the key reservoirs of the system as a result of the daily operation of the system are given in Figures 10 through 14.

Contributions of the In-Delta Storage Facilities

These operation studies did not include any limitations on diversion resulting from the monitoring of the population of the Delta smelt in the vicinity of the diversion pumps. It was assumed that the FMWT index was always greater than the threshold value of 239. Also the WQMP criteria for the limits on the concentration of organic carbon were not included in these simulation runs. As indicated in the introduction to this report, the water quality impacts of the operation of the In-Delta Storage Facilities will be assessed later in a set of simulation runs using the DWR Delta Simulation Model (DWRDSM2). Inclusion of the above criteria on limiting the allowable diversion and discharge could reduce the contribution to the system's delivery capability indicated by these simulation runs.

The current CALSIM operation studies showed that the size of the combined storage in both Webb Tract and Bacon Island was small enough as compared to the amount of water available for diversion to storage that both islands could be filled almost every year, with the obvious exception of critical and dry years. The simulation run also showed that the rules governing the export of the stored water in these islands were not overly stringent to prevent full utilization of the storage facilities in most years. Figures 15 through 17 show the operation of these facilities. Figure 17 is a detailed comparison of operation between the two facilities over a 29-month period. This comparison brings out the fact that the longer period of allowable discharge from Bacon Island allows the facility to fill more than once in a water year, whereas the opportunity for multiple filling in Webb Tract is practically eliminated by the inability to discharge the stored water until July. For this reason, the priority of filling up to the conversation storage was given to Bacon Island. The incorporation of these storage facilities in the system increased the long-term average delivery capability of the system by 117 TAF per year. Figures 18 through 20 show the changes in annual deliveries to SWP south-of-Delta Contractors, the interruptible deliveries made by SWP, and the CVP south-of-Delta Contractors. The changes in the end-of-month storage in the key reservoirs of the system induced by the operation of the In-Delta Storage Facilities are shown in Figures 21 through 25

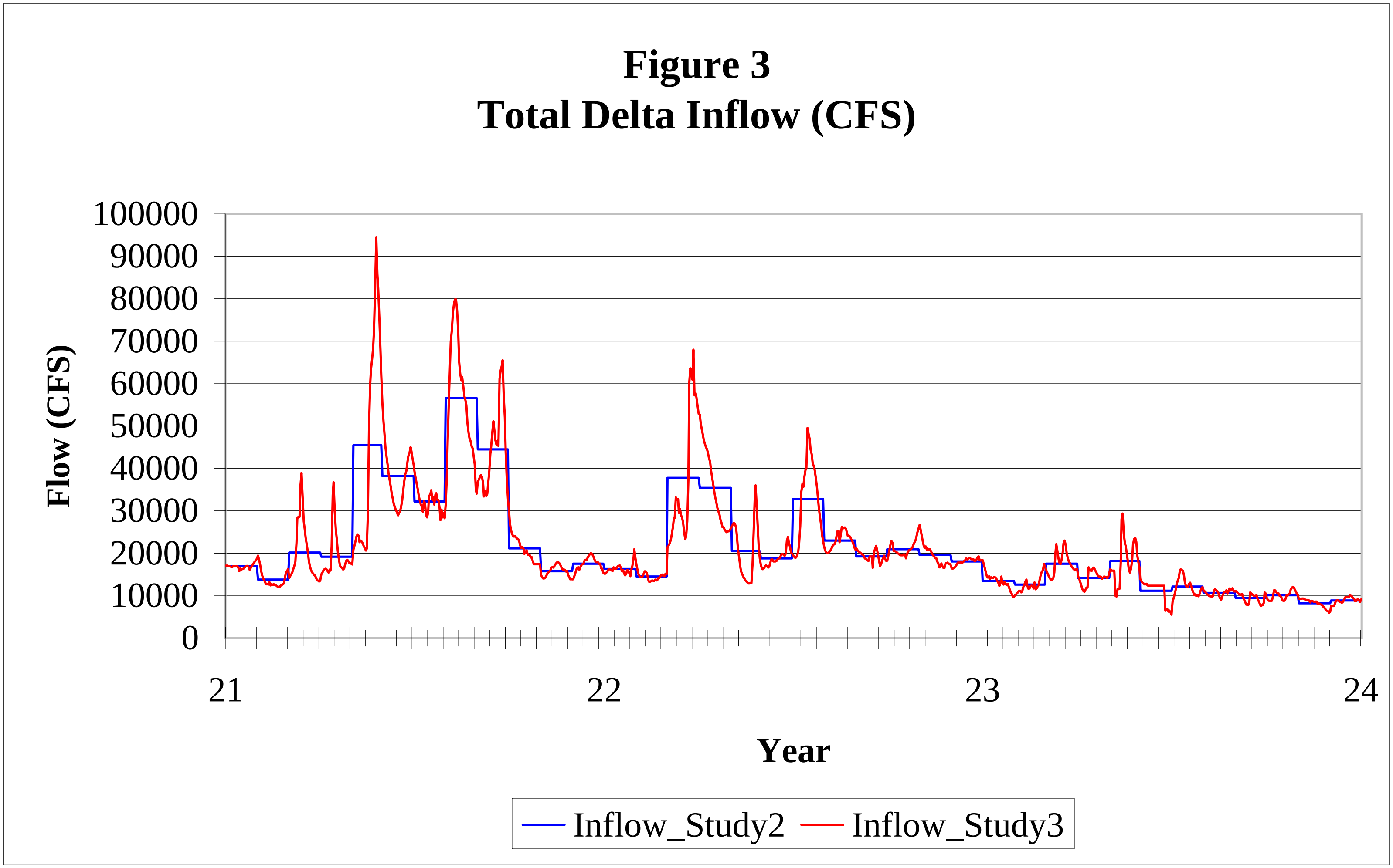


Figure 3
Total Delta Inflow (CFS)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Flow (CFS)
21
22
23
24
Year
Inflow_Study2
Inflow_Study3

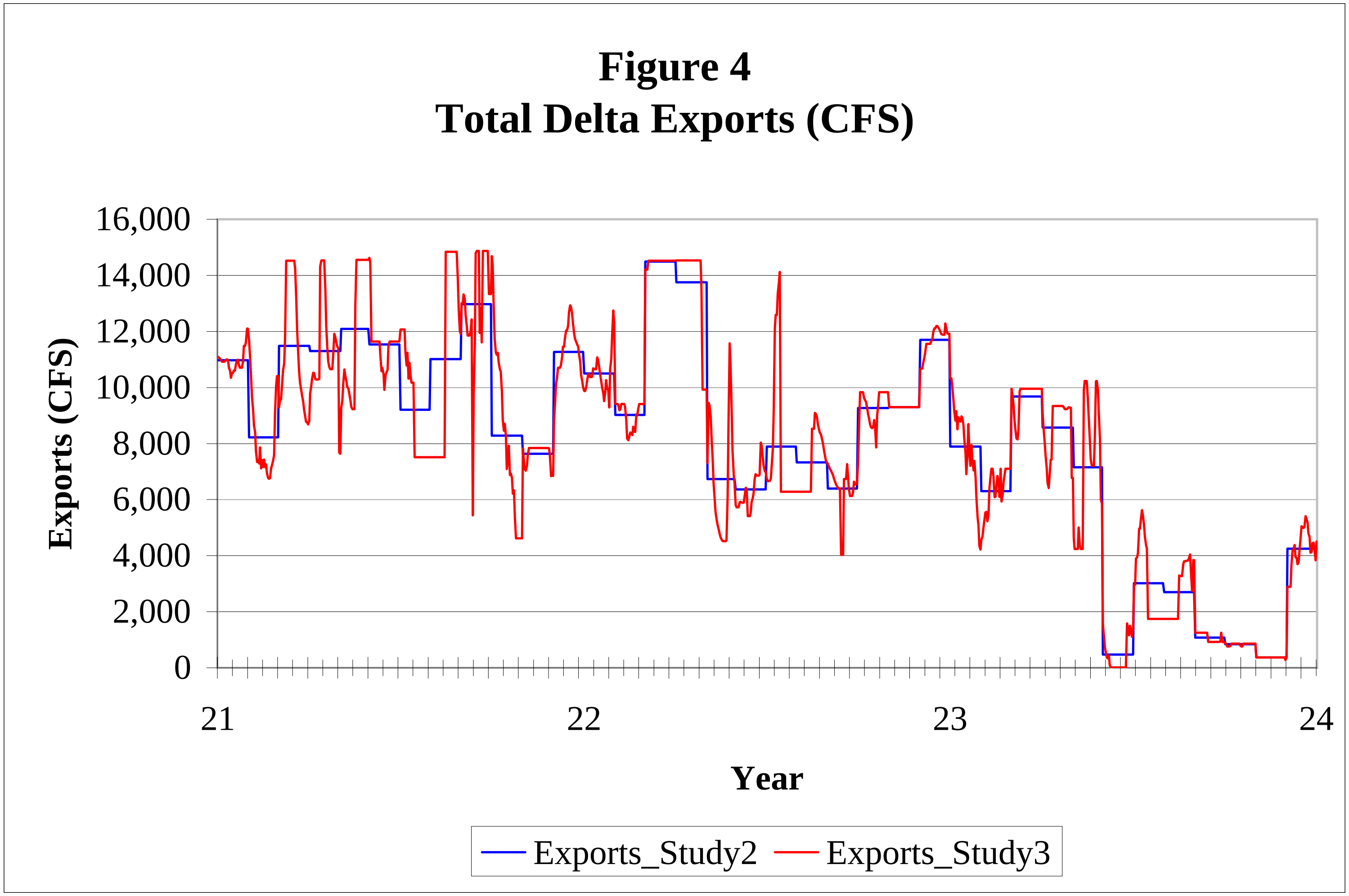
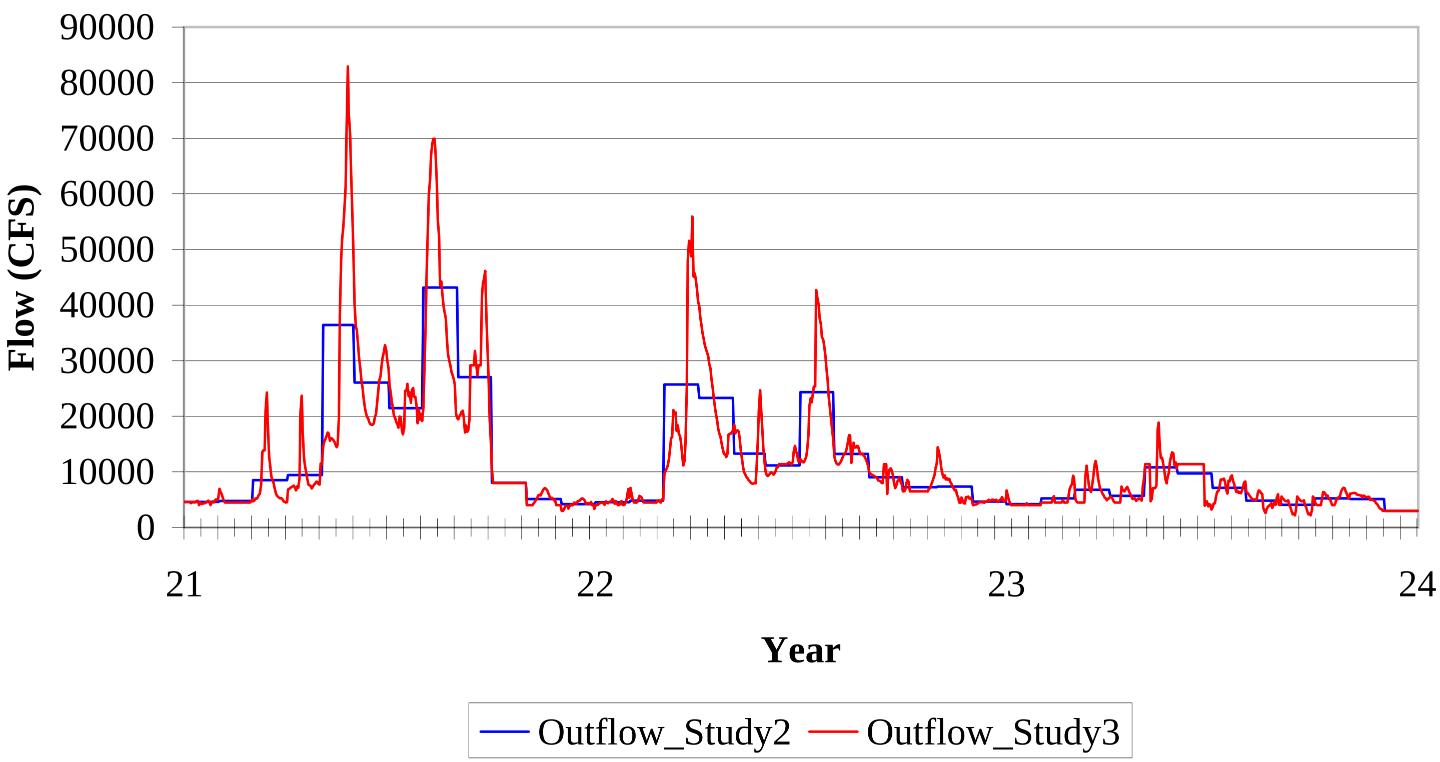


Figure 4
Total Delta Exports (CFS)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Exports (CFS)
21
22
23
24
Year
Exports_Study2
Exports_Study3

Figure 5
Net Delta Outflow (CFS)



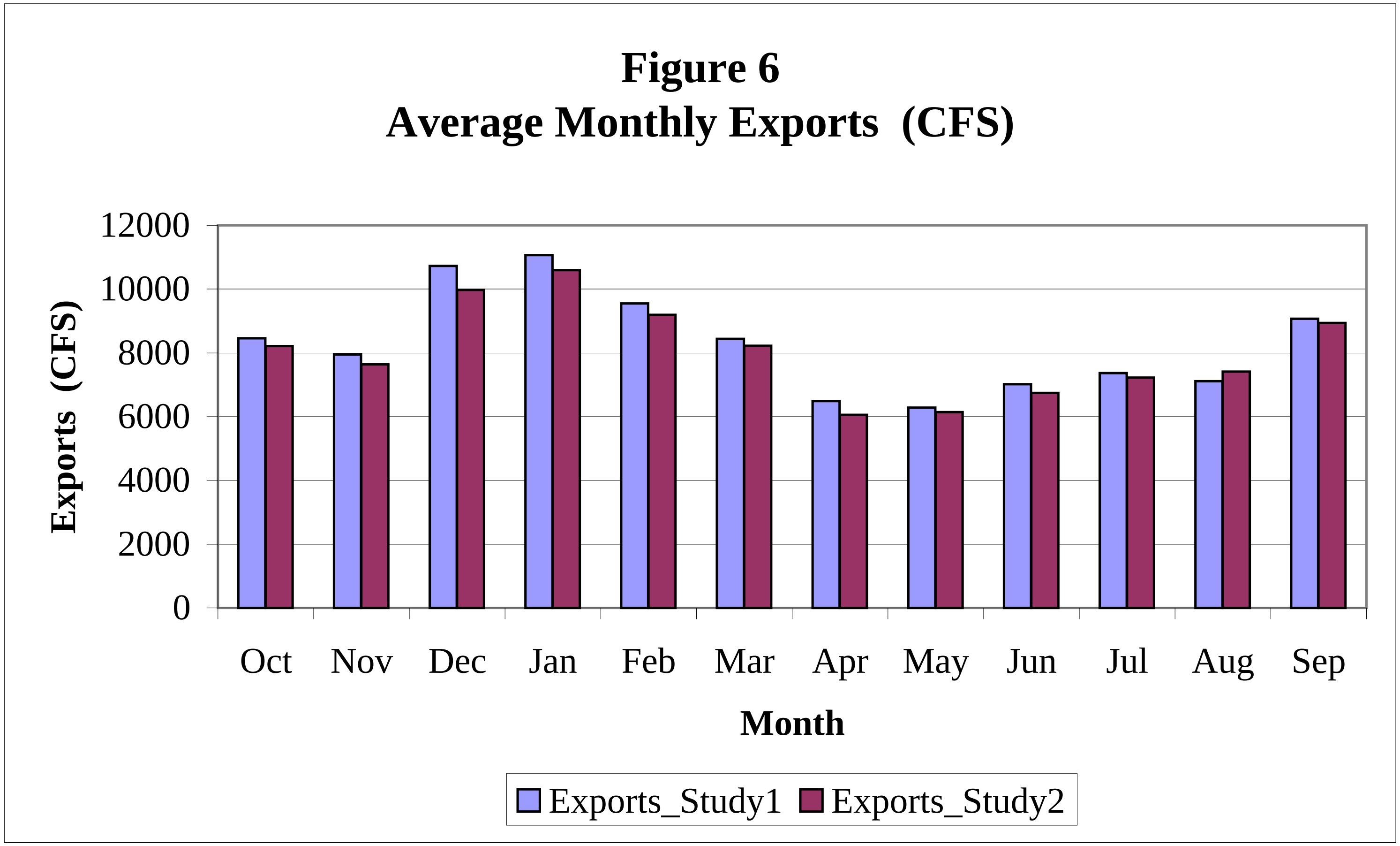


Figure 6
Average Monthly Exports (CFS)
12000
10000
8000
6000
4000
2000
0
Exports (CFS)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Exports_Study1
Exports_Study2

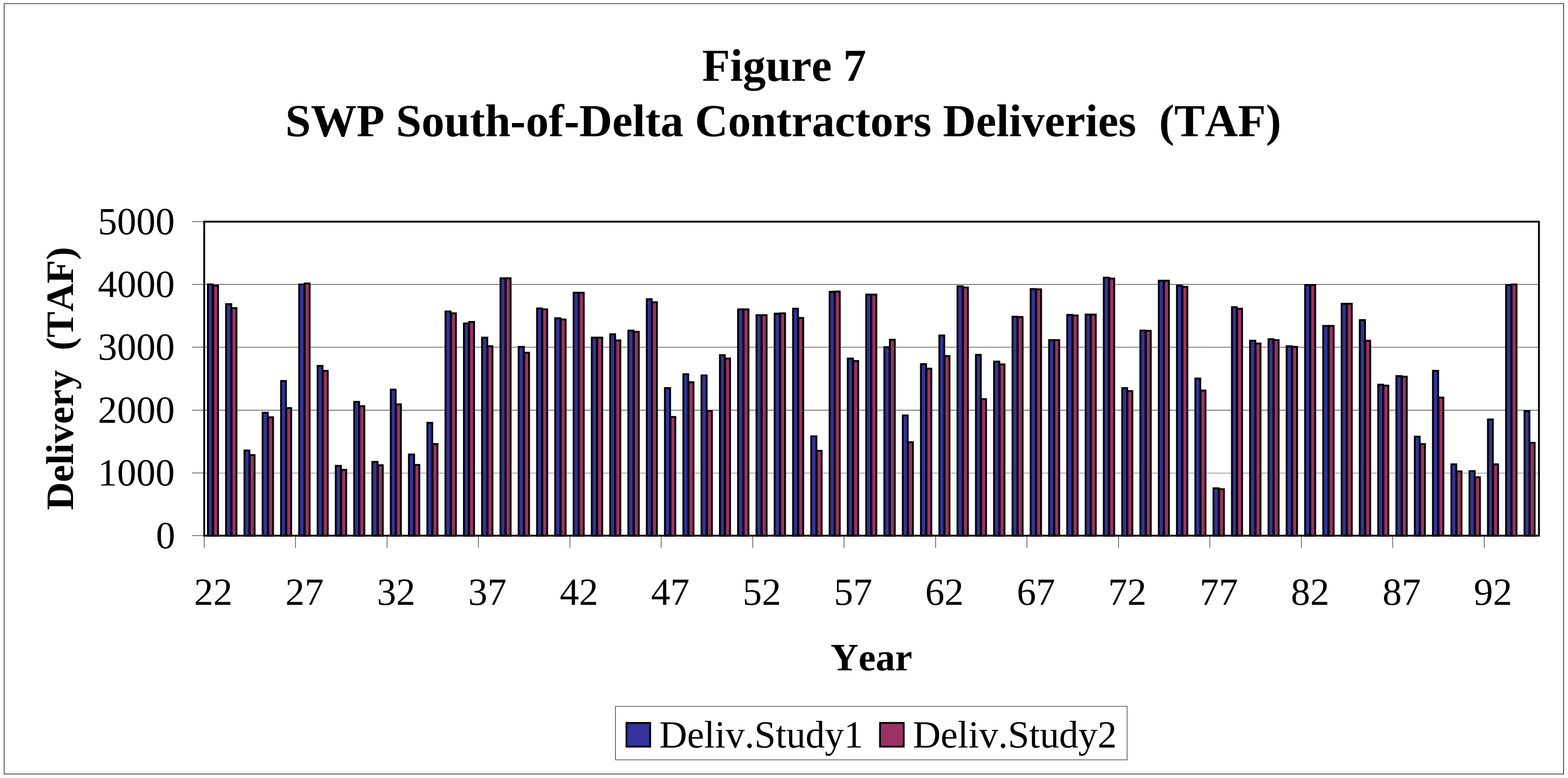
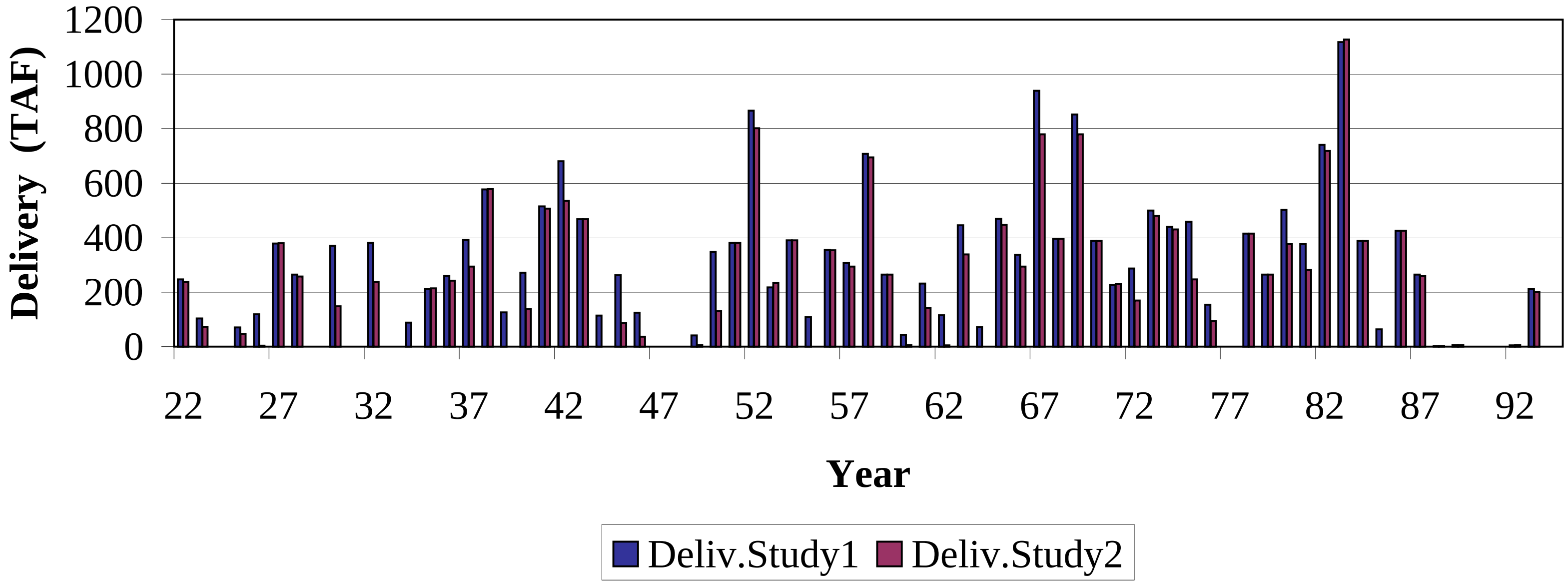


Figure 7
SWP South-of-Delta Contractors Deliveries (TAF)
5000
4000
3000
2000
1000
0
Delivery (TAF)
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
Year
Deliv.Study1
Deliv.Study2

Figure 8
SWP South-of-Delta Interruptible Deliveries (TAF)



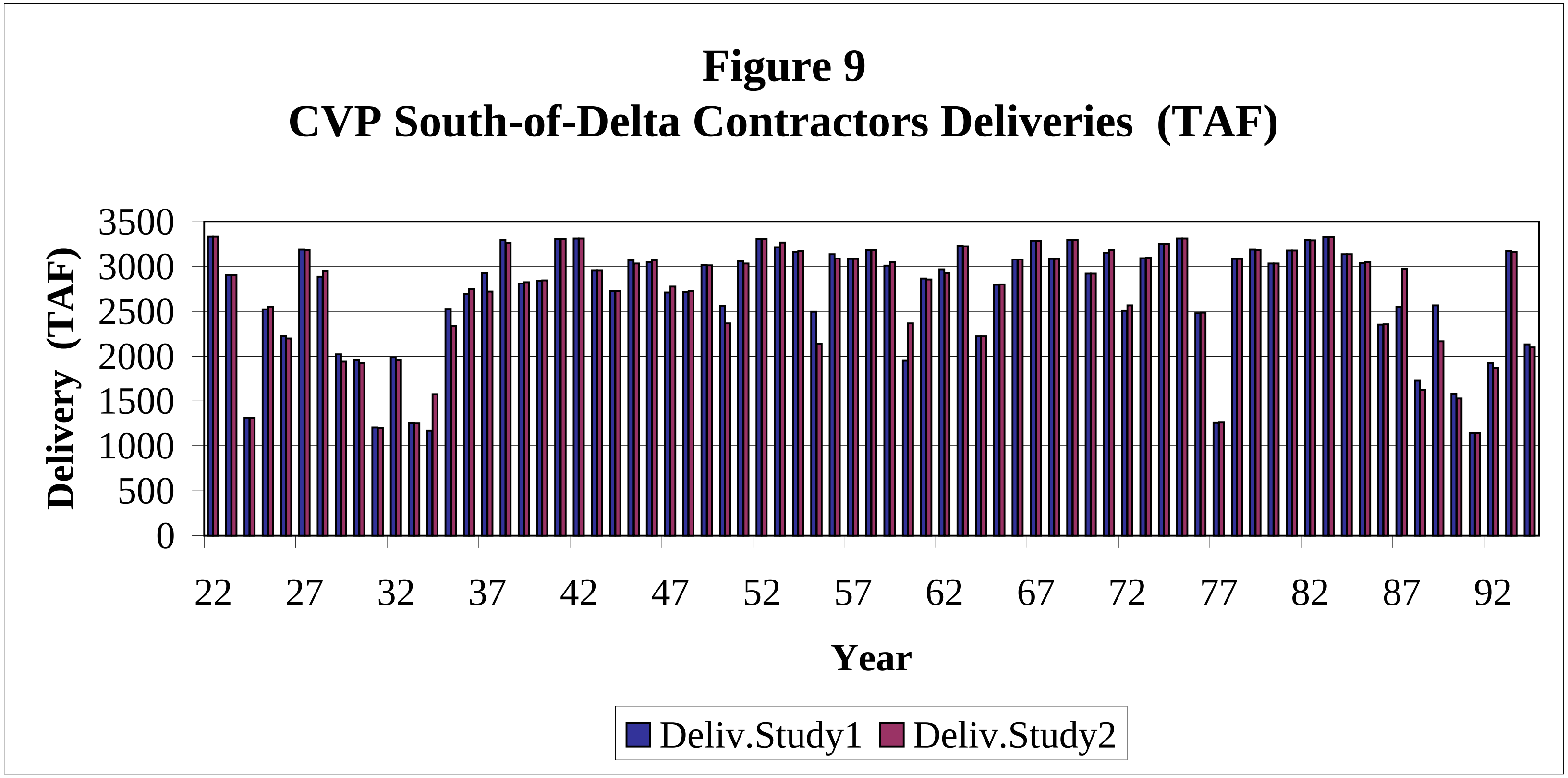


Figure 9
CVP South-of-Delta Contractors Deliveries (TAF)
Delivery (TAF)
3500
3000
2500
2000
1500
1000
500
0
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
Year
Deliv.Study1
Deliv.Study2

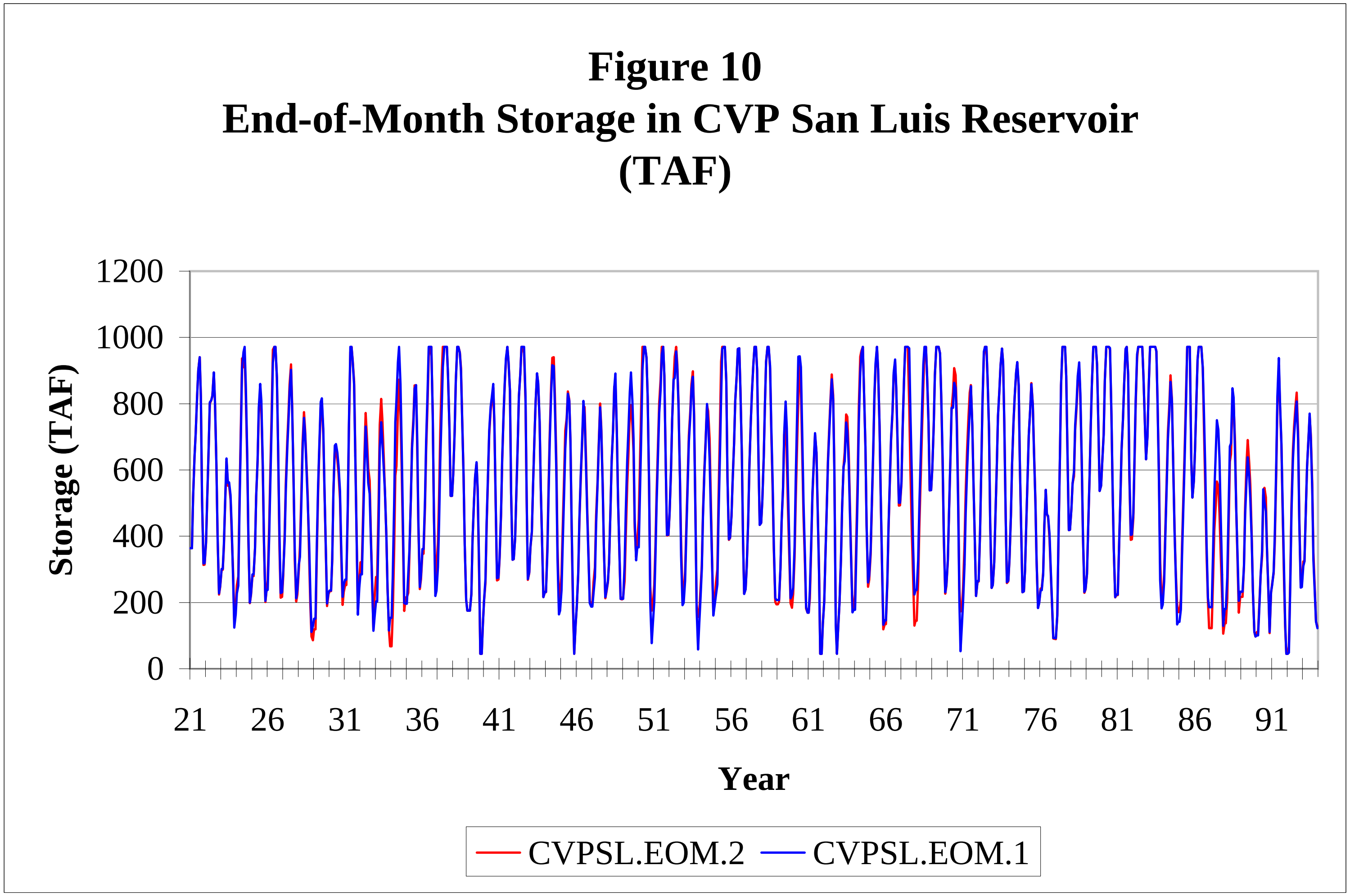
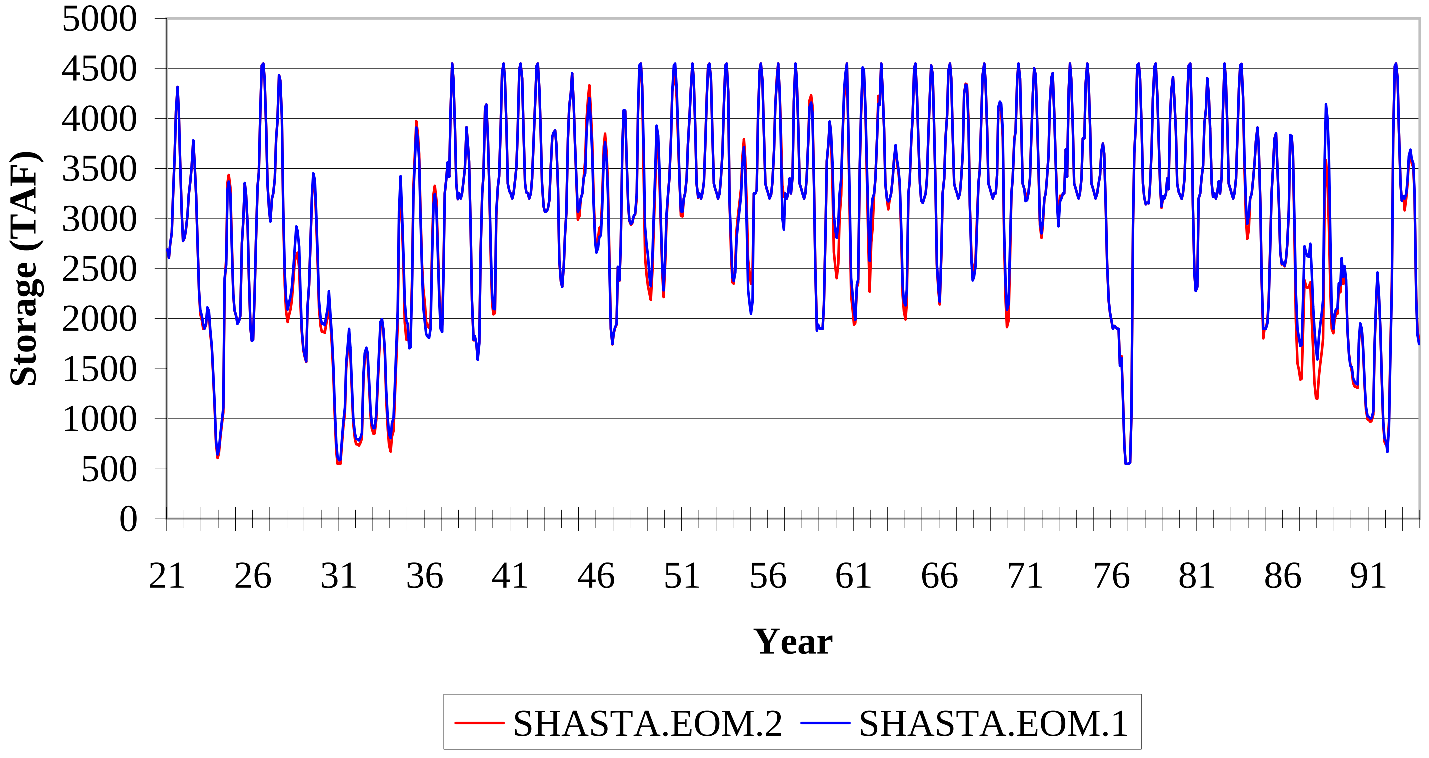


Figure 10
End-of-Month Storage in CVP San Luis Reservoir
(TAF)
Storage (TAF)
1200
1000
800
600
400
200
0
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
CVPSL.EOM.2
CVPSL.EOM.1

Figure 11
End-of-Month Storage in Shasta Lake (TAF)



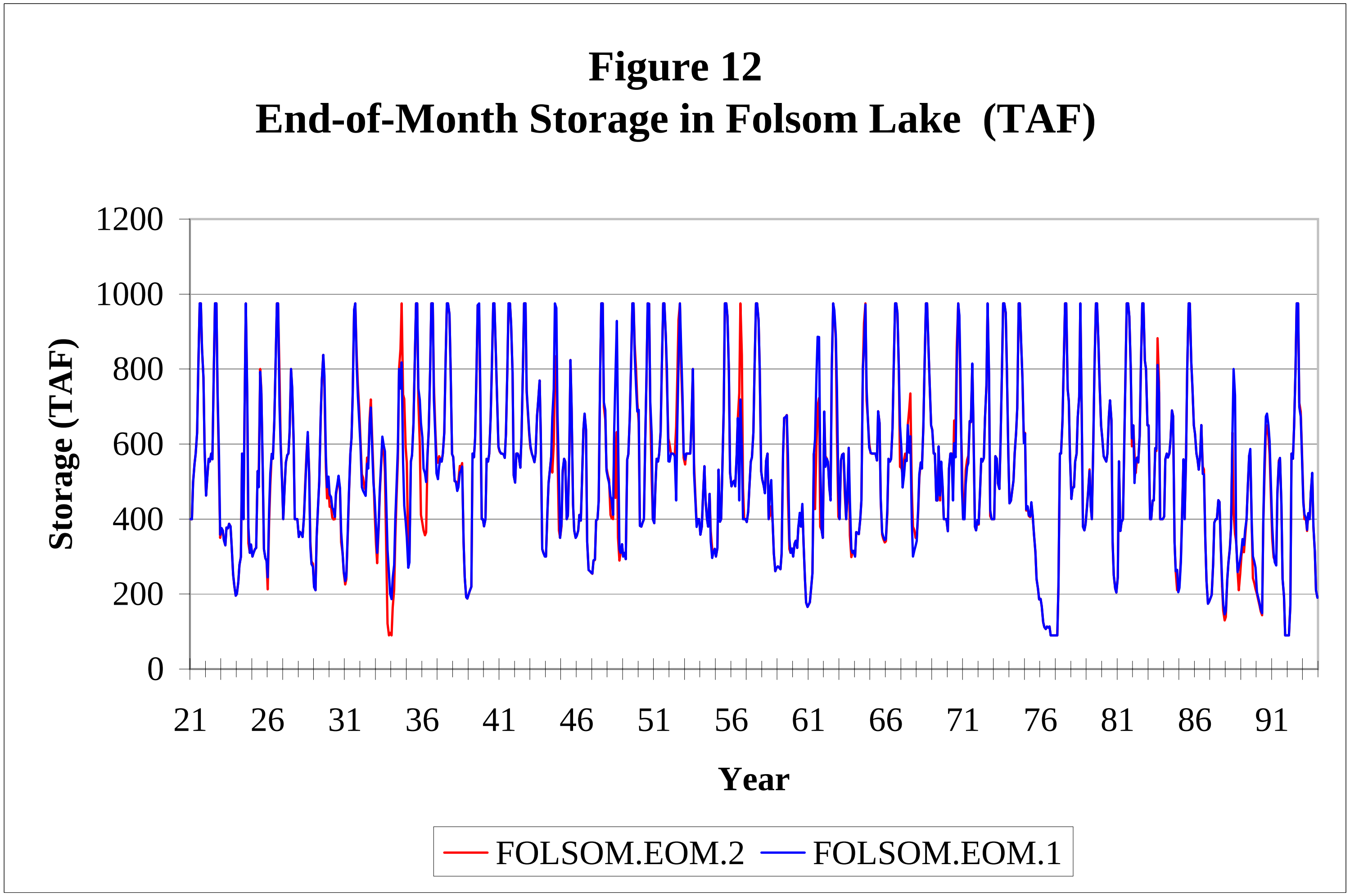


Figure 12
End-of-Month Storage in Folsom Lake (TAF)
Storage (TAF)
1200
1000
800
600
400
200
0
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
FOLSOM.EOM.2
FOLSOM.EOM.1

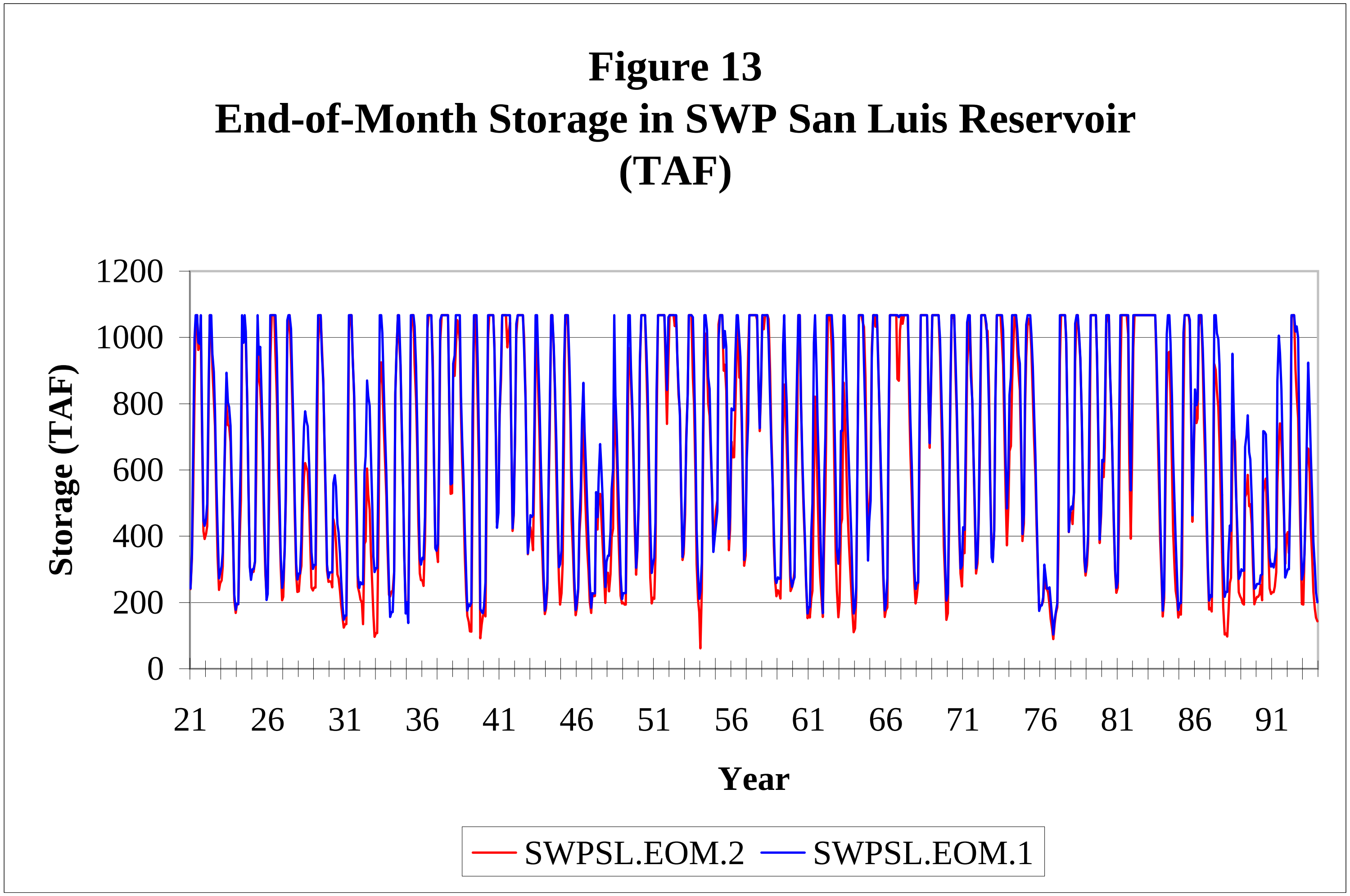


Figure 13
End-of-Month Storage in SWP San Luis Reservoir
(TAF)
Storage (TAF)
1200
1000
800
600
400
200
0
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
SWPSL.EOM.2
SWPSL.EOM.1

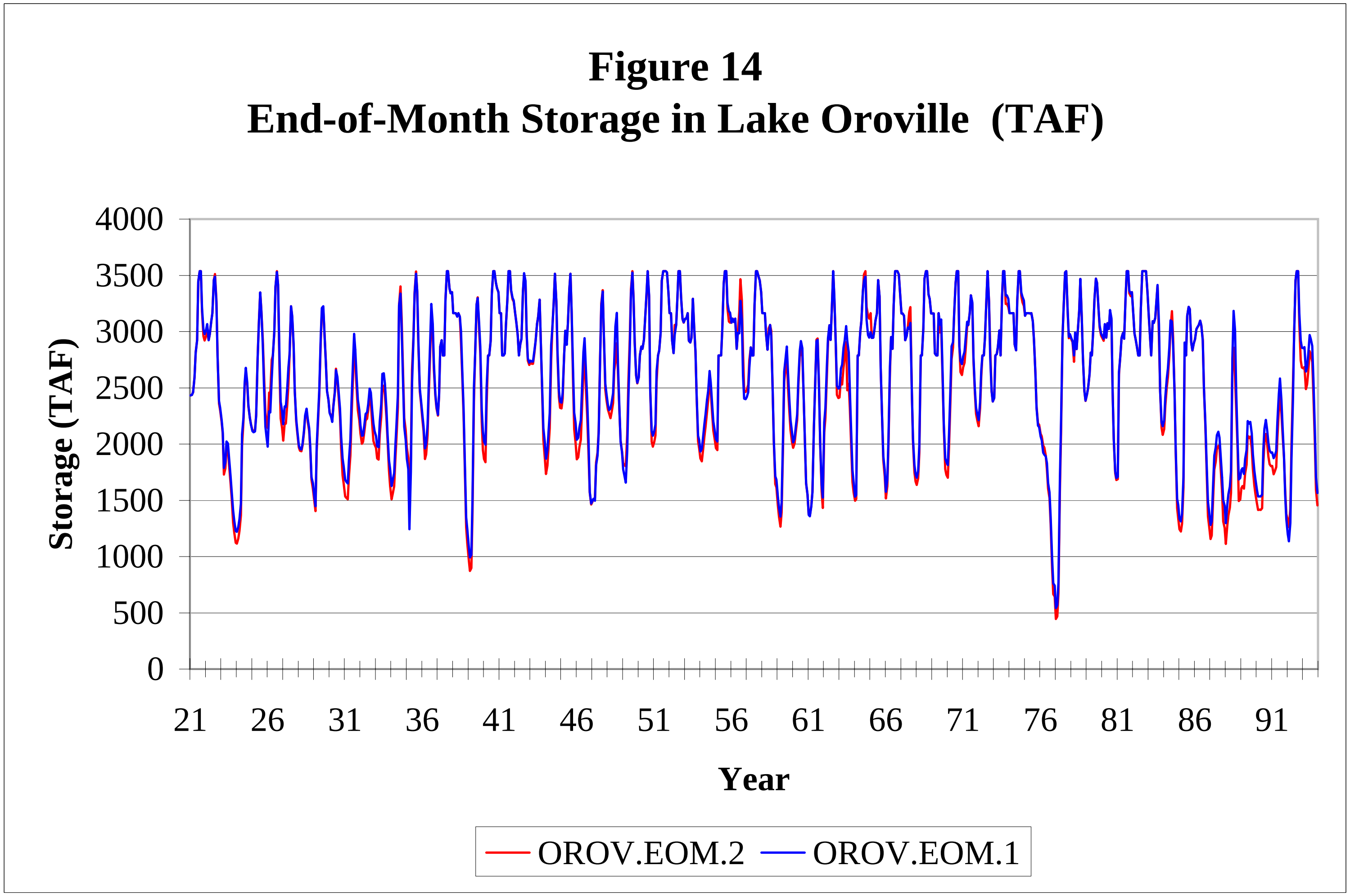
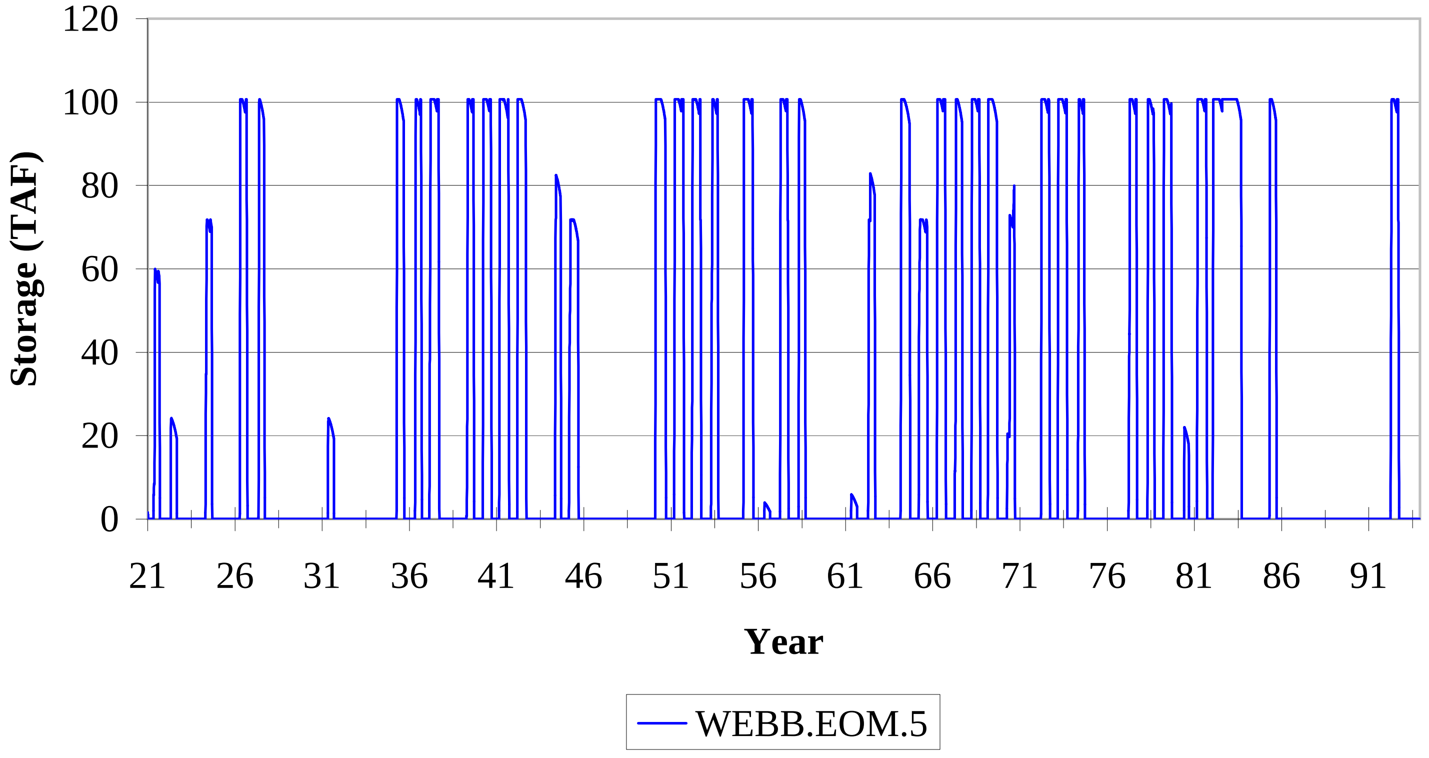


Figure 14
End-of-Month Storage in Lake Oroville (TAF)
4000
3500
3000
2500
2000
1500
1000
500
0
Storage (TAF)
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
OROV.EOM.2
OROV.EOM.1

Figure 15
End-of-Month Storage in Webb Tract (TAF)



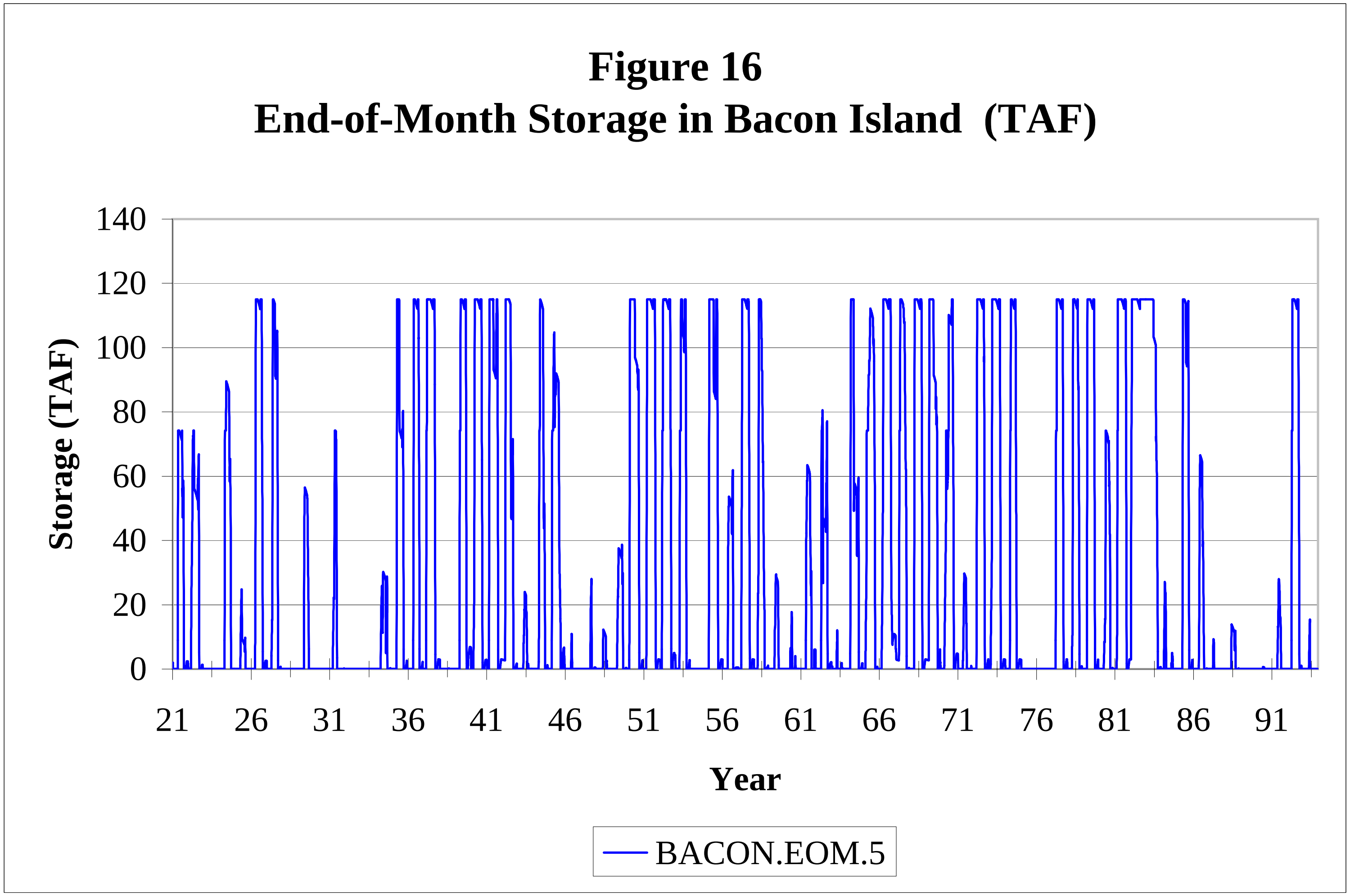


Figure 16
End-of-Month Storage in Bacon Island (TAF)
140
120
100
80
60
40
20
0
Storage (TAF)
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
BACON.EOM.5

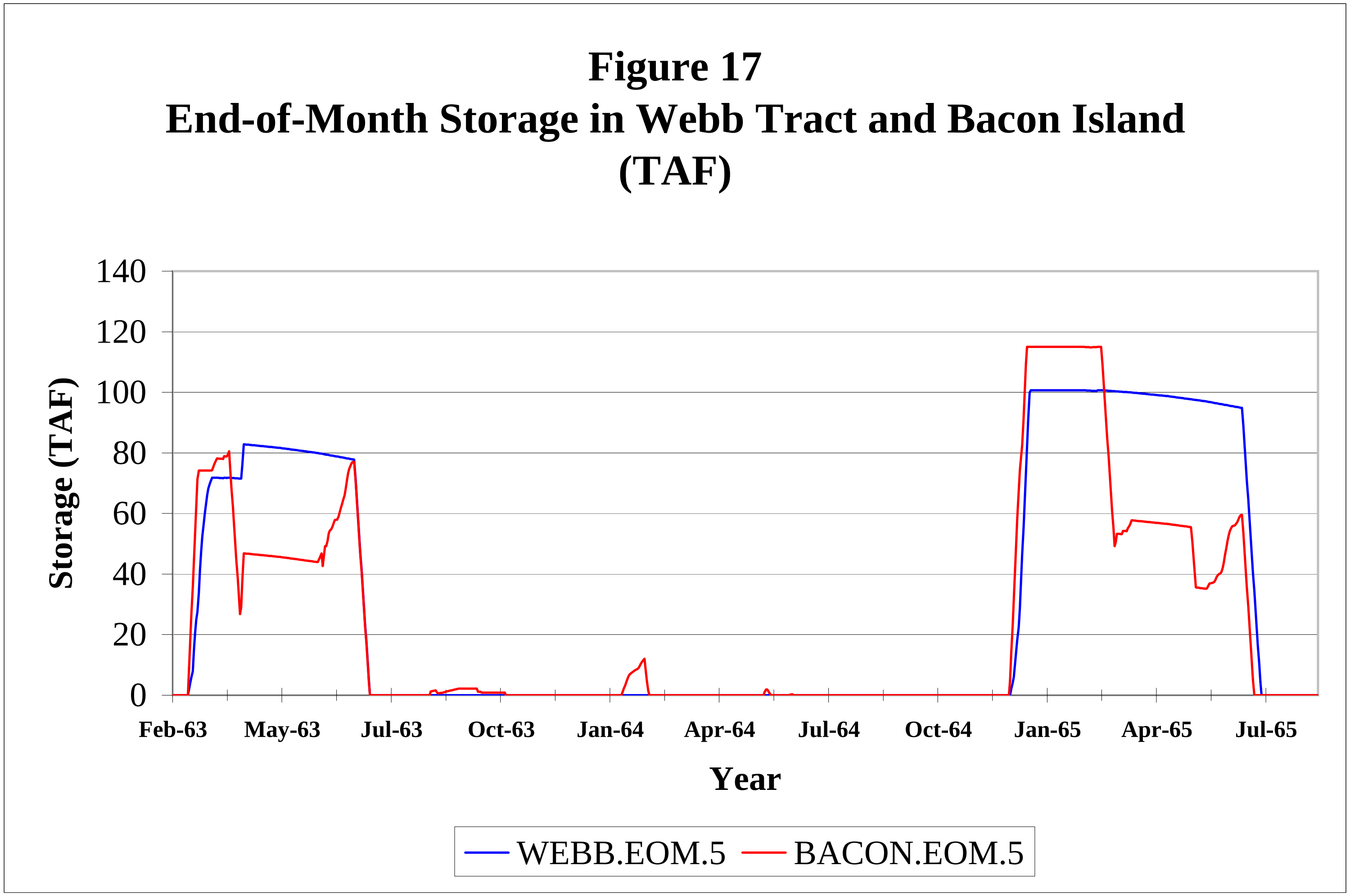


Figure 17
End-of-Month Storage in Webb Tract and Bacon Island
(TAF)
140
120
100
80
60
40
20
0
Storage (TAF)
Feb-63
May-63
Jul-63
Oct-63
Jan-64
Apr-64
Jul-64
Oct-64
Jan-65
Apr-65
Jul-65
Year
WEBB.EOM.5
BACON.EOM.5

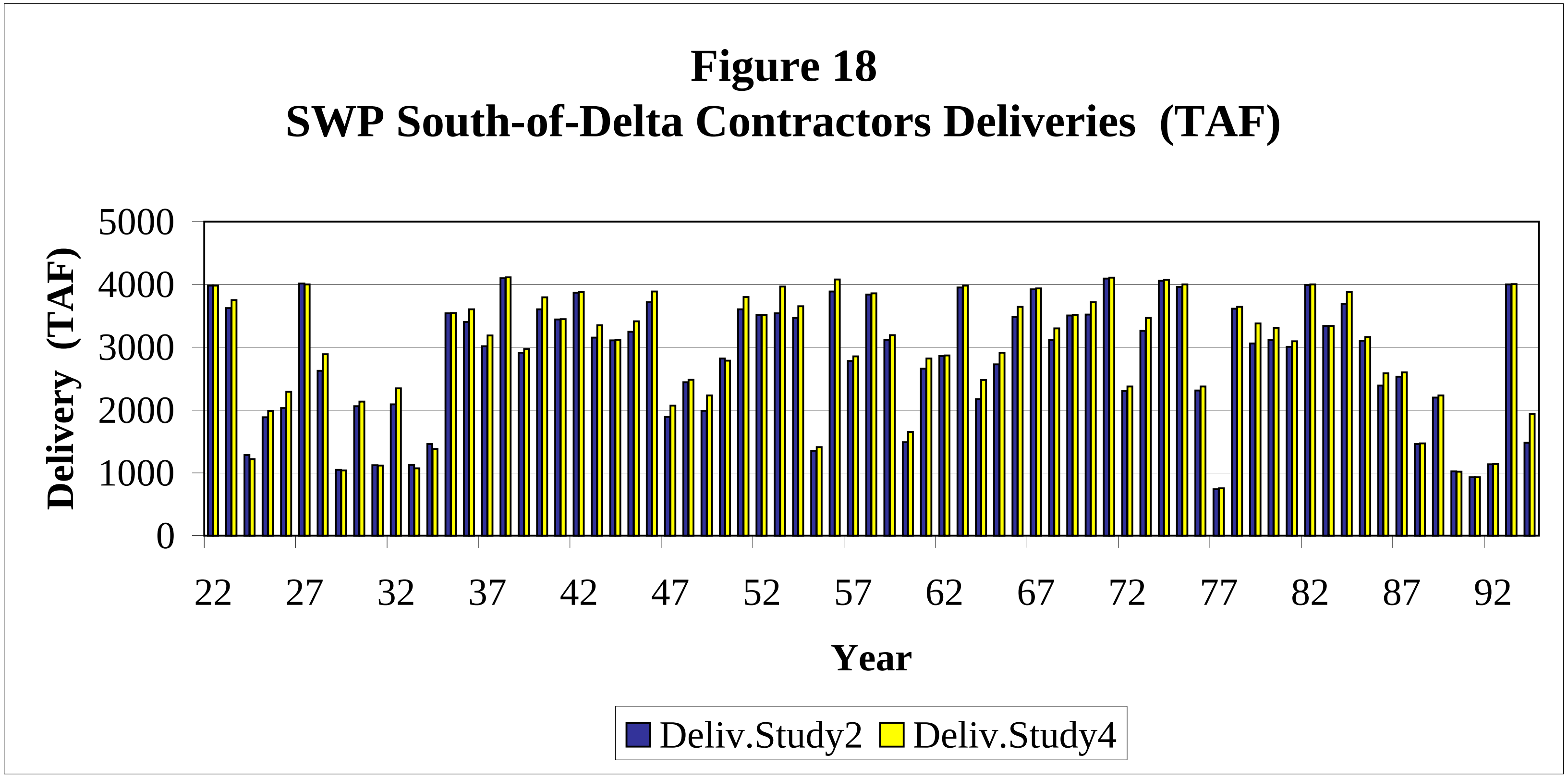


Figure 18
SWP South-of-Delta Contractors Deliveries (TAF)
Delivery (TAF)
5000
4000
3000
2000
1000
0
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
Year
Deliv.Study2
Deliv.Study4

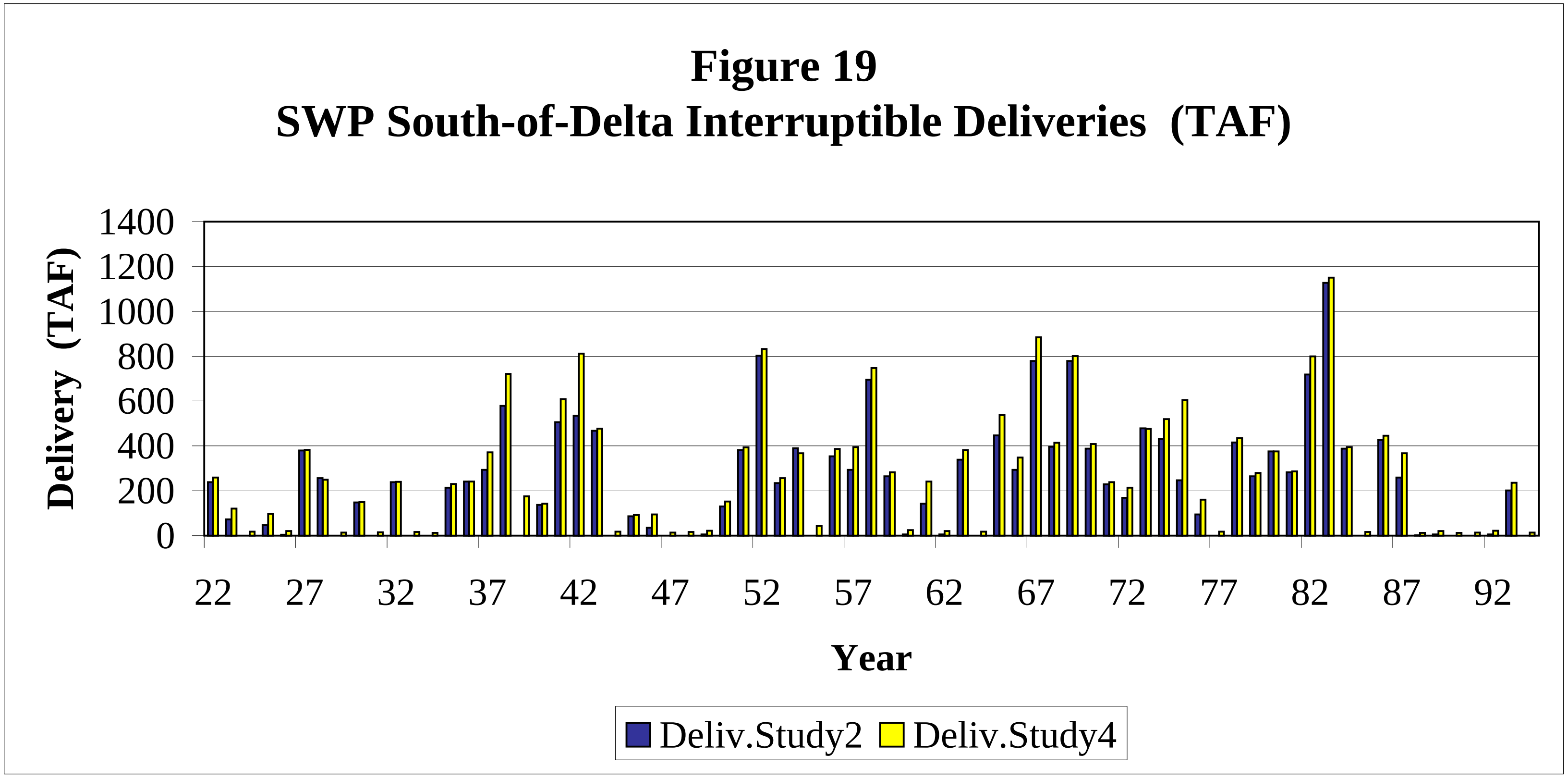


Figure 19
SWP South-of-Delta Interruptible Deliveries (TAF)
1400
1200
1000
800
600
400
200
0
Delivery (TAF)
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
Year
Deliv.Study2
Deliv.Study4

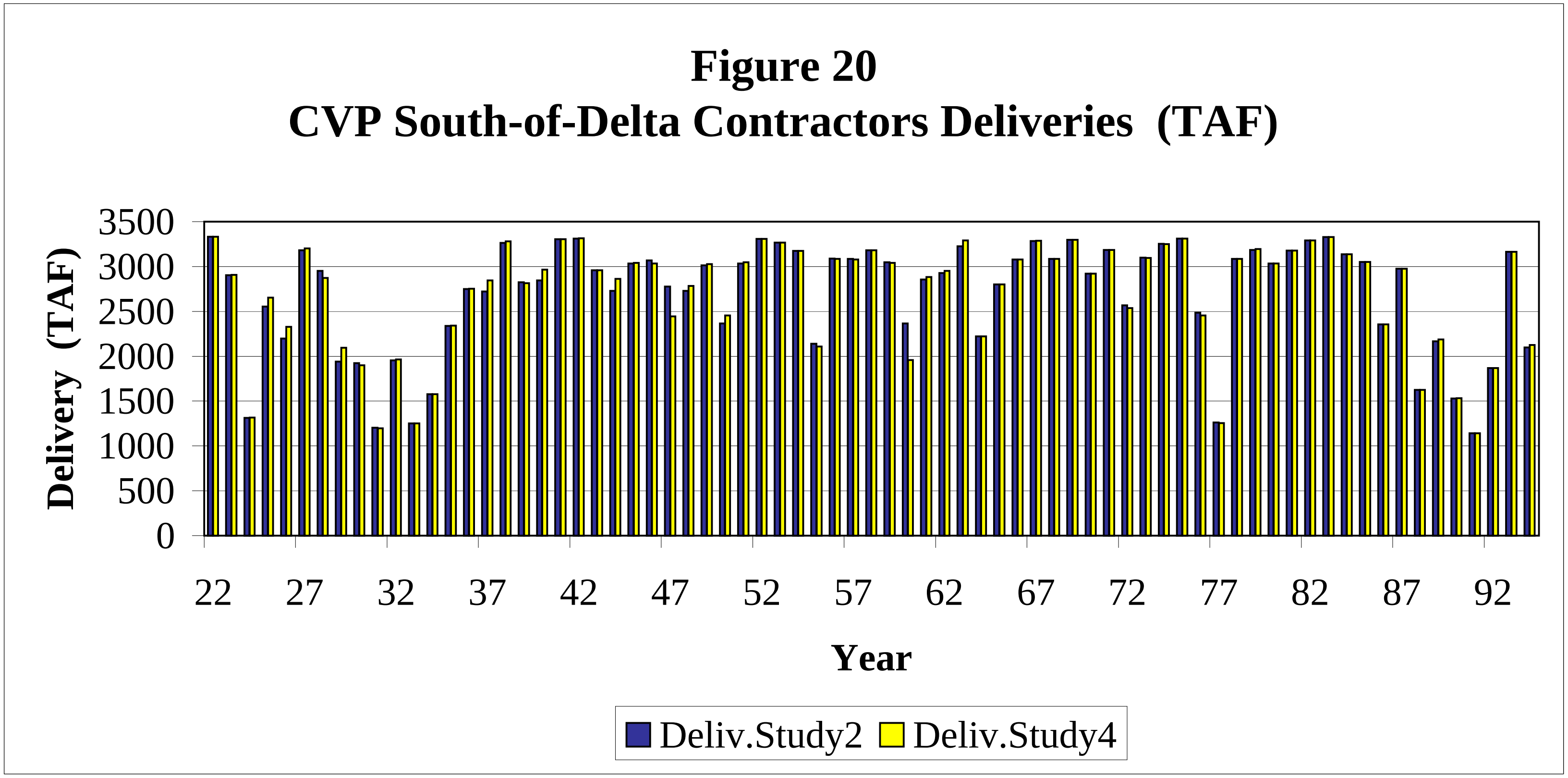
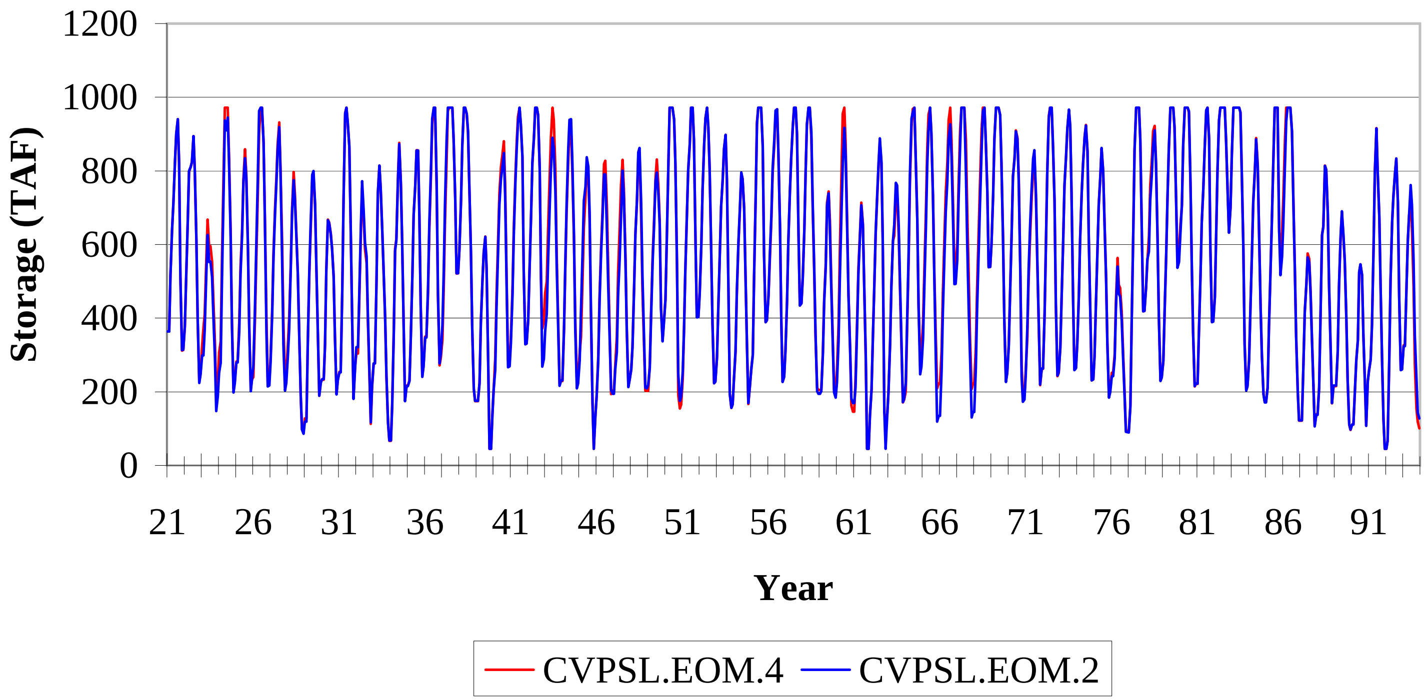


Figure 20
CVP South-of-Delta Contractors Deliveries (TAF)
3500
3000
2500
2000
1500
1000
500
0
Delivery (TAF)
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
Year
Deliv.Study2
Deliv.Study4

Figure 21
End-of-Month Storage in CVP San Luis Reservoir (TAF)



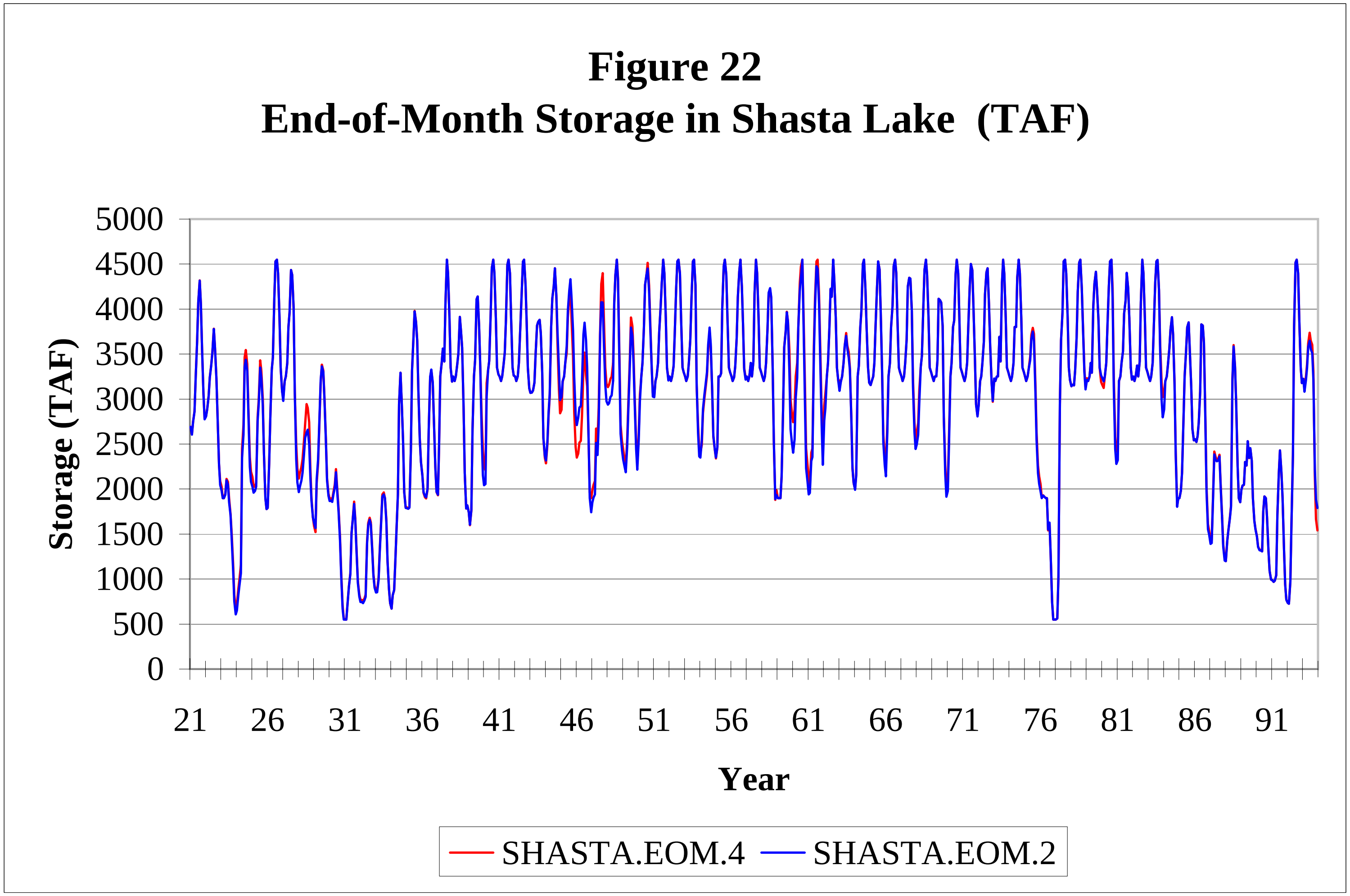


Figure 22
End-of-Month Storage in Shasta Lake (TAF)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Storage (TAF)
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
SHASTA.EOM.4
SHASTA.EOM.2

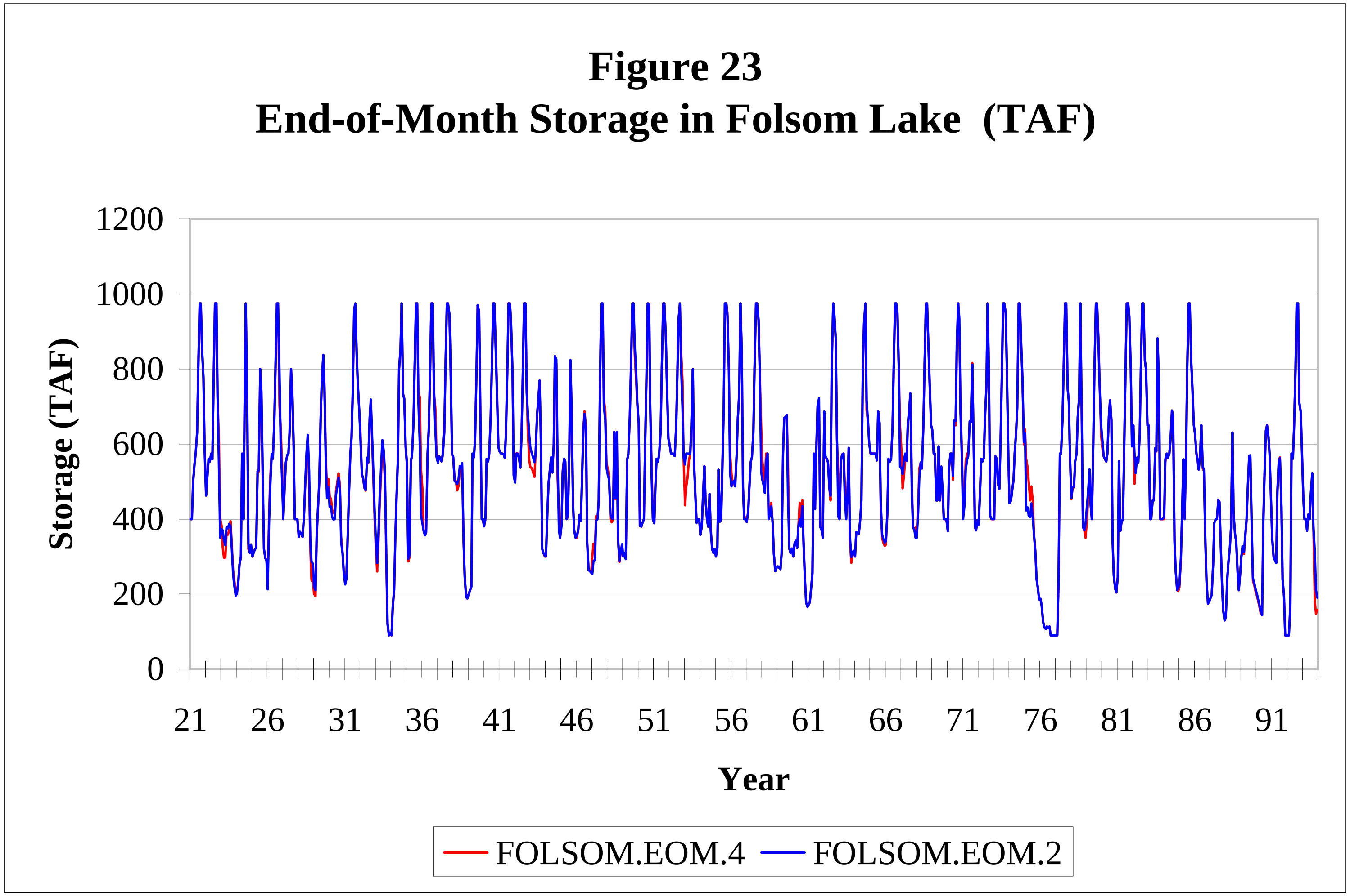


Figure 23
End-of-Month Storage in Folsom Lake (TAF)
1200
1000
800
600
400
200
0
Storage (TAF)
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
Year
FOLSOM.EOM.4
FOLSOM.EOM.2

Figure 24
End-of-Month Storage in SWP San Luis Reservoir
(TAF)

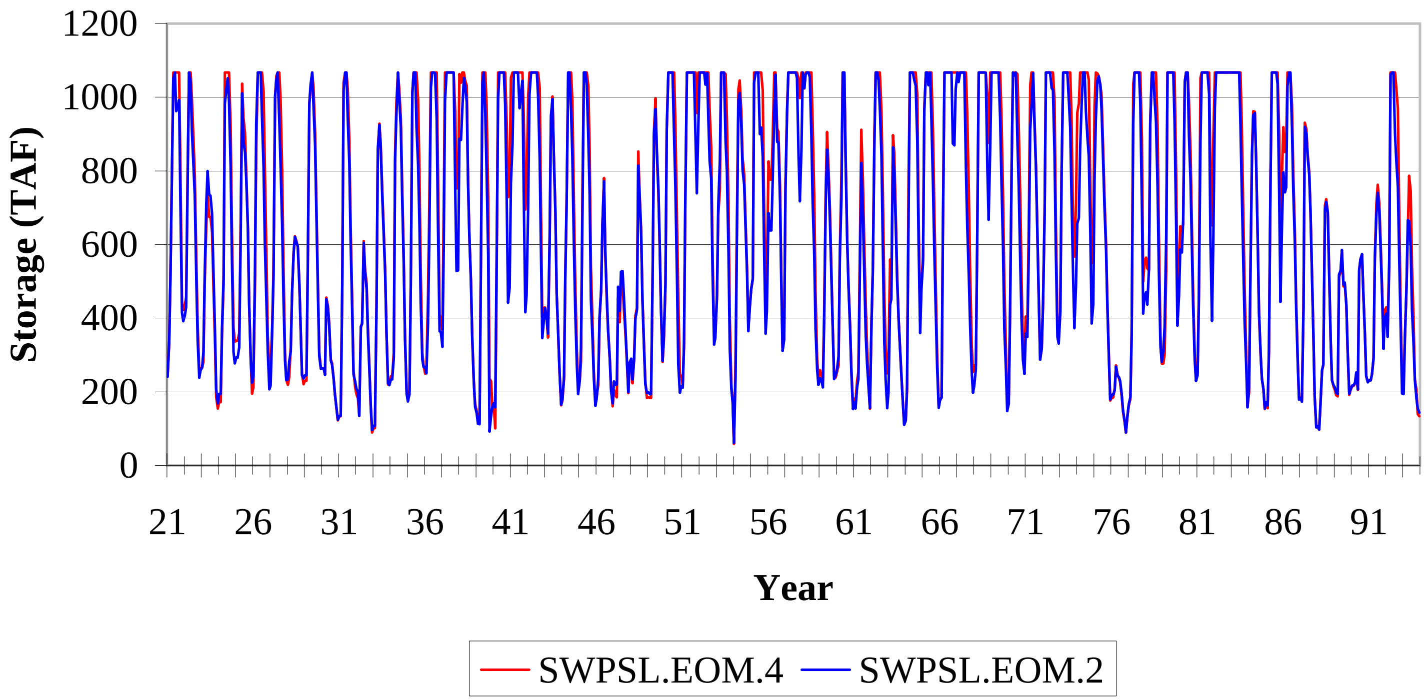


Figure 25
End-of-Month Storage in Lake Oroville (TAF)